BIOLOGY IN DAILY LIFE

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BIOLOGY

IN

DAILY

LIFE

By

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PREFACE

THE FUNCTIONS OF THE BIOLOGY COURSE

A modern course of biology must serve the needs of two important groups of pupils: those whose formal education will terminate before or upon the completion of high-school work, and those who will continue their schooling through college.

The biological materials of greatest interest and value to the members of the first group are likely to be of optimal appeal and worth, also, to those of the second. The latter, however, must secure, in addition, a foundation of biological knowledge sufficiently broad and complete to enable them to continue, without handicaps, their study of biology in college.

The content of this book (determined in large part through research) and its organization and methods of presentation (refined through many years of teaching, of supervising high-school classes in biology, and of working with teachers of the subject) are planned to serve the needs of both these groups of pupils. In the selecting of the content, moreover, care has been taken to ensure that the requirements of various state and city syllabuses are adequately met.

THE OBJECTIVES OF THE BIOLOGY COURSE

For many years the major objectives of high-school biology, as announced by authoritative committees,[1] have remained essentially the same:

To develop functional understandings of biological principles.

To develop scientific attitudes ("As Scientists Think").

To develop an understanding of the importance of scientific method, and facility in its use ("As Scientists Work").

Abundant investigational evidence is available which indicates clearly that such objectives are not attained to an appreciable extent incidentally or as an inevitable concomitant of studying subject matter, but that they can be substantially achieved only when materials specially designed to effect them are taught directly.

In this book, therefore, such materials are presented definitely, persistently, and diversely.

[1]The Thirty-first Yearbook of the National Society for the Study of Education, Part I, *A Program for Teaching Science.* Public School Publishing Company, Bloomington, Illinois, 1932.

Science in General Education, the Report of the Committee on Science Instruction of the Progressive Education Association. D. Appleton-Century Company, Inc., New York, 1938.

The Forty-sixth Yearbook of the National Society for the Study of Education, Part I, *Science Education in American Schools.* The University of Chicago Press, Chicago, Illinois, 1947.

READING COMPREHENSION

Every high-school teacher knows that with many pupils reading disabilities constitute a major hindrance to learning. A special effort has been made throughout this textbook to facilitate reading comprehension. The organization is simple, logical, and obvious. The longer parts are divided into conveniently short, numbered sections. Short sentences and short paragraphs are used. The vocabulary is carefully controlled in accordance with a combination of the findings of three extensive research investigations of vocabulary.[1] Scientific terms, and some nonscientific words as well, are defined—sometimes in the body of the text, sometimes in footnotes, and sometimes by means of the illustrations. Every scientific term is pronounced in a footnote on the page where the pupil is likely first to encounter it.

ADJUSTMENT TO INDIVIDUAL DIFFERENCES IN PUPILS

A major aim in the construction of any course is that the course shall provide materials and activities which will permit optimal adjustment to the individual differences and capacities of the learners. Several devices have been incorporated into this book to serve as effective aids to teachers in achieving this extremely difficult outcome. The following four paragraphs briefly discuss some of these devices:

Through Designating Essential Materials

The biological materials deemed of special importance to everybody were selected by a jury of experienced teachers of high-school biology. The paragraphs containing these materials are designated by **E** (essential). Unfortunately, though inevitably, the most important materials are not always those most easily comprehended.

Through Providing a Varied Program to Stimulate Reflective Thinking

An increasing number of educators believe that the success and value of a course may be measured in large part by the amount and quality of reflective thinking stimulated by it. Recent research evidence has revealed the types of "thought questions" which stimulate reflective thinking in science courses.[2] All these types will be found in the legends of illustrations and in the recurring section entitled "Applying Your Knowledge of Biology." The questions, moreover, are of graduated difficulty; they range from those simple enough to be answered by all who may study the book to those difficult enough to challenge the highest abilities in a class. The numerous materials under "As Scientists Work and Think" provide another varied and graded program for stimulating reflective thinking.

[1]Edward L. Thorndike, *A Teacher's Word Book of the Twenty Thousand Words Found Most Frequently and Widely in General Reading for Children and Young People.* Bureau of Publications, Teachers College, Columbia University, New York, 1931.

B. R. Buckingham and E. W. Dolch, *A Combined Word List.* Ginn and Company, Boston, 1936.

Francis D. Curtis, *Investigations of Vocabulary in Textbooks of Science for Secondary Schools*, Chap. III. Ginn and Company, Boston, 1938.

[2]Francis D. Curtis, "Types of Thought Questions in Textbooks of Science," *Science Education* (September–October, 1943), Vol. XXVII, pp. 60–67.

Through Refining the Scientific Vocabulary

The scientific vocabulary presented in this book is determined from the results of the latest stage in an investigation which was begun in 1930.[1] Two lists, "essential" terms (designated by two asterisks) and "important" terms (designated by single asterisks), have been constructed from the pooled judgments of independent juries of teachers of high-school biology. Each of these two lists numbers about one hundred and seventy terms. Several hundred other terms are included in the book, so that every pupil may extend his biological vocabulary beyond the list of "essential" terms. The Glossary, besides defining all the "essential" and "important" terms, defines also many others.

Through Providing a Varied and Graded Array of Activities

Activities of the kinds that have been found to stimulate the interest and challenge the ability of boys and girls are provided here in unusual number and variety. They will be found in the legends of illustrations and in the special features under "Applying and Extending What You Know," at the ends of chapters.

ADJUSTMENT TO DIFFERENCES IN CLASSES

This book has been planned to facilitate adjustment not only to differences among pupils, but also to the interests, needs, and capacities of different classes. The entire content is organized so as to provide the teacher with maximum freedom in planning the selection and the order of presentation of major subject-matter divisions. For example, with some classes it will seem desirable to consider the classification of plants and animals in considerable detail; with others it will seem preferable to omit the formal study of this material entirely. As presented in this book, classification may be studied in whole or in part, or it may be entirely omitted, as may seem best for the class.

INTEGRATION

The results of several recent studies reveal that the illustrations of textbooks function with relatively little effectiveness as learning aids to pupils, and that most pupils disregard them as materials for study. Devices are employed throughout this book to assist the teacher in inducing the pupils to study the materials as a whole, and not as separate divisions of text, illustrations, suggested activities, etc. These devices include citing each illustration at one or more points in the text where it will facilitate the comprehension of text materials; placing in the legends of illustrations supplementary subject matter, even certain essential materials; directing the pupil's attention at various points to specific activities presented in "Applying and Extending What You Know," which supplement the text discussions; and placing in the tests ("Checking What You Know") items that call for a knowledge of the materials in legends and special features.

[1]Francis D. Curtis, *A Further Refinement of the List of Glossary Terms for Biology.* Unpublished study.

Frequent footnote references relate concepts and bind them together by directing the pupil to relevant materials in other places in the text. Such references encourage him to review, integrate, and extend what he has studied.

LEARNING AIDS

The devices already described are all valuable as learning aids. Special attention, however, is directed to these features:

The frequent recurring groups of tests are intended primarily as a self-testing device. The sections of short-answer items, designed to measure knowledge of subject matter, can be made to serve a twofold purpose: they can be used as inventory tests, or pretests, if taken before a division is studied; and as a measure both of knowledge gained and of knowledge possessed (achievement) if taken again after the study of the chapter. The tests are so grouped and indicated that they can be used either with the individual short sections or with the whole chapters.

The tests in this book are supplemented abundantly by the *Tests to Accompany Biology in Daily Life*. The extensive testing program provided by the latter not only further measures factual knowledge, but also evaluates the pupil's ability to use facts in problem situations; his understanding of biological principles and scientific method; his recognition of the various scientific attitudes; and his achievement of other objectives of a well-rounded course of biology.

The *Workbook to Accompany Biology in Daily Life* both implements and supplements the text with abundant and varied additional activities.

A *Teachers' Manual and Key* not only provides the answers to all the questions asked in the text and the workbook, together with discussions of the activities included in these books, but also presents lists of motion pictures, apparatus, and professional readings, as well as other materials of practical value to teachers of biology.

ACKNOWLEDGMENTS

A list of all the teachers of biology and others who have contributed materials and suggestions for this book, which has long been in process of construction, would occupy many more pages than are here available. The authors wish, however, to acknowledge their great indebtedness to the following specialists, for critical readings of the portions of the manuscript dealing with their fields of specialization, or for providing invaluable source materials or consultative services: Dr. Irving C. Anderson, Dr. Warren R. Chase, Dr. Avery C. Test, Dr. Robley C. Williams, Dr. Arthur E. Woodhead, and Arthur C. Curtis, M.D., L. Dell Henry, M.D., Leonard E. Himler, M.D., and George R. Moore, M.D.—all of the University of Michigan; Dr. J. G. Brown and Dr. Charles T. Voorhies, of the University of Arizona; Dr. W. Edgar Martin, Specialist in Biology, Federal Security Agency, Office of Education, and Dr. E. Eugene Irish, biologist and specialist in the teaching of science; Dr. W. Edgar Martin and Dr. Oreon Keeslar, for permission to adapt their lists of biological principles and elements of scientific method respectively, as determined from their research; W. W. Bauer, M.D., of the American Medical Association; Mrs. John L. Wierengo, Regional Commander of the American Cancer Society, Inc.; Louis I. Dublin, of the Metropolitan Life Insurance Company; Mrs. Helen Urban, specialist in dietetics; and Lloyd Mason Smith, Director, Palm Springs Desert Museum.

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THIS BOOK AND YOU

Whenever anybody speaks of studying, he usually means reading something to get the meaning out of it. In order to be able to "get your lessons," therefore, you must be able to read and understand what is assigned in your text-book or in other books. Here are some suggestions which other students have found useful in studying biology. You may find among them some that will prove useful, too.

FIRST, GET ACQUAINTED WITH YOUR TEXTBOOK

Examine the table of contents to find out what the major divisions of the course in biology are. Then leaf through the text and read a sentence or a paragraph here and there. Examine some of the illustrations and their legends to see what sorts of materials they contain.

Look for paragraphs in the text marked with **E**. These paragraphs are the most important ones in the book. They contain subject-matter which it is highly desirable for everybody to know. Look for sentences in the text which are marked with **P**. These statements are biological principles—statements that are true of many or perhaps all living things.

Examine some of the sections under "Applying and Extending What You Know," in order to find out what boys and girls do in studying biology besides reading the text. Turn to pages 570 and 571 and examine the material under "As Scientists Work" and "As Scientists Think." Read the introduction to the Glossary to see what helps that section provides. Examine the Index to become familiar with the aid it offers.

MAKE YOUR STUDY TIME COUNT

In discussing reading and studying, one of the world's great scholars recently wrote, "Whatever I read, I read it as if I were going to have to take an examination on it afterward." For him, when he was trying to learn content, and was not merely "skimming" to get a general idea of content, there was no difference between reading something and studying it. He stated also that he had trained himself to pay such close attention while reading that he never needed to read anything more than once in order to know all that was in it.

Not all of us can do the latter, but we can all try. If we do, we shall learn to read better.

When you begin to study an assignment, first "get your bearings." Leaf the material through. Read the paragraph headings one after another, to see how the material is organized. Then begin to read (study) the assignment, paragraph by paragraph, trying meanwhile to keep your attention from wandering *at all.* Examine each illustration and carefully read its legend at the point where the reference to the illustration is made. When you have finished reading a

paragraph, stop and try to recall all that is in it. If you cannot (and at first perhaps you will not be able to do so), read it carefully again. Your goal is to train yourself so that you will never have to read any part *more* than twice in order to know what is in it.

Continue in this way through the assignment. Then stop again and try to recall the most important points in all of it. If necessary, refer back to the parts which you think important but do not clearly recall.

Now you are ready to take the tests under "Checking What You Know" which cover the assignment that you have just studied. You may find, especially at first, that in order to answer all the items correctly (as you are expected to be able to do), you will have to do more reading here and there.

If you follow the plan for study just outlined, you will soon find that your reading ability is improving and that you are able to get your lesson thoroughly in less time than at first.

Many successful students follow the practice of jotting down every assignment in a small notebook when the assignment is made.

EXTEND YOUR VOCABULARY

Perhaps you have heard the saying "Words are the tools of thought." This means that the more words a person knows and can readily use, the better able he is to think clearly, to say exactly what he means, and to understand what he hears and reads.

By Reviewing Rules for Word-Building

Many persons could add to their vocabularies by reviewing some of the rules for word-building, such as the following ones, which they learned earlier, but may have forgotten. Maybe you could profit by reviewing them.

Un-, *dis-*, *non-*, or *in-* or (sometimes) *im-*, at the beginning of a word, gives it a meaning opposite from that which it would have without the syllable. Examples are "*un*-scientific," "*dis*infect," "*non*-green," "*in*-accurate," and "*im*mature."

At the beginning of a word, *mis-* gives the meaning "wrongly," as in "*mis*place" ("place wrongly").

At the end of a word, *-less* gives the meaning "without," as in "color*less*" ("without color");

-al gives the meaning "belonging to," "pertaining to," or "being like," as in "botani*cal*" ("belonging to or pertaining to botany");

-y gives the meaning "having," "full of," "like," or "characterized by," as in "wood*y*" ("like wood") or "bon*y*" ("full of bones" or "like bone");

-ive gives the meaning "having the nature or quality of" or "having to do with," as in "digest*ive*" ("having to do with digestion");

-ion gives the meaning "act of" or "process of," as in "digest*ion*" ("process of digesting");

-en gives the meaning "made of," as in "wood*en*" ("made of wood");

-ic gives the meaning "pertaining to," as in "alcohol*ic*" ("pertaining to alcohol").

By Learning New Biological Terms

There are hundreds of biological terms in this book, but only about one hundred and seventy of them are "essential" terms, and

an equal number are "important" terms. The "essential" terms are indicated by two asterisks (**). You should learn the meaning or meanings of every one of these "essential" terms, and how to spell, pronounce, and use it correctly.

The "important" terms are indicated by a single asterisk (*). These terms and all those not indicated by asterisks are included in this book so that you can acquire a larger vocabulary than just the list of "essential" terms if you wish to do so, as nearly all students do. (See the footnote on page 3.)

You will find a considerable number of terms derived from Latin (or from Greek by way of Latin) whose singular forms end in *-um* (as *Paramecium*), *-us* (as *coccus*), or *-a* (as *alga*), and whose plurals end, respectively, in *-a* (*paramecia*), *-i* (*cocci*), or *-ae* (*algae*).

Use every biological term that you decide to "master" as often as you can in your thinking, your talking, and your writing. By doing this you will soon find yourself using the term almost without realizing that you are doing so.

By Using the Glossary Frequently

You will find the Glossary a major aid to you in increasing your biological vocabulary. It will serve you as a limited "biological dictionary" for all the "essential" and "important" terms, and for many other terms as well. You will be more likely to understand and to remember a term if you see how it is used. Therefore make it your practice, when you look up a term in the Glossary, to turn to the page referred to at the end of the definition, and to read the paragraph or the legend or to examine the diagram that contains the term.

By Using the Index

Make it your practice to use the Index for locating the definitions or explanations, indicated by *def.*, of terms not included in the Glossary.

USE THE FOOTNOTES

Footnotes are one of the most useful features of any book. Form the habit of always reading the footnotes and of making use of them whenever you can. Probably the kinds of footnotes that you will most frequently find useful in this book are (1) those that furnish the pronunciations and definitions of biological terms, and (2) those that help you to review and "tie together" what you know, by referring you to other parts of the book where the same topics are discussed or the same terms are used.

KEEP CHECKING WHAT YOU KNOW

The tests provided under "Checking What You Know" cover the entire contents of the book, including materials in the legends of illustrations and some of the exercises under "Applying and Extending What You Know." The tests, especially those on "Biological Facts" and "Biological Terms," will enable you to find out how much you

know about the materials in a section *before* you have studied it, as well as *afterward.*

The short-answer tests under "Biological Facts" are chiefly of three types:

The Modified Multiple-Response Type

Each item of this type has five or more endings. Among these endings there may be, or there may not be, one which makes the statement correct. You must decide in every case whether the correct ending is or is not present. If it is, indicate it by the number which precedes it. If it is not, supply an ending that will make the statement true.

Here is an example of an item in which the correct ending appears among the five:

> The study of plants and animals is included in (1) geology; (2) botany; (3) chemistry; (4) biology; (5) physics.

You would indicate (4) as the ending that makes the statement correct.

An example of an item in which none of the endings makes the statement correct is this:

> The study of plants and animals is included in (1) paleontology; (2) botany; (3) chemistry; (4) geology; (5) physics.

You would need to supply another ending, *biology*, in order to make the statement correct.

The Modified True-False Type

Some statements of this type are correct as they are, and others are not. If a statement is not correct, make it so by changing the *italicized* word or one or more of the italicized words.]

> The study of plants and animals is included in *biology.*

This statement is true and therefore needs no change.

> The study of plants and animals is included in *botany.*

This statement is not true, but you can make it so by changing *botany* to *biology.*

The Completion Type

With this type, supply for each blank a word or a phrase that will make the statement true, thus:

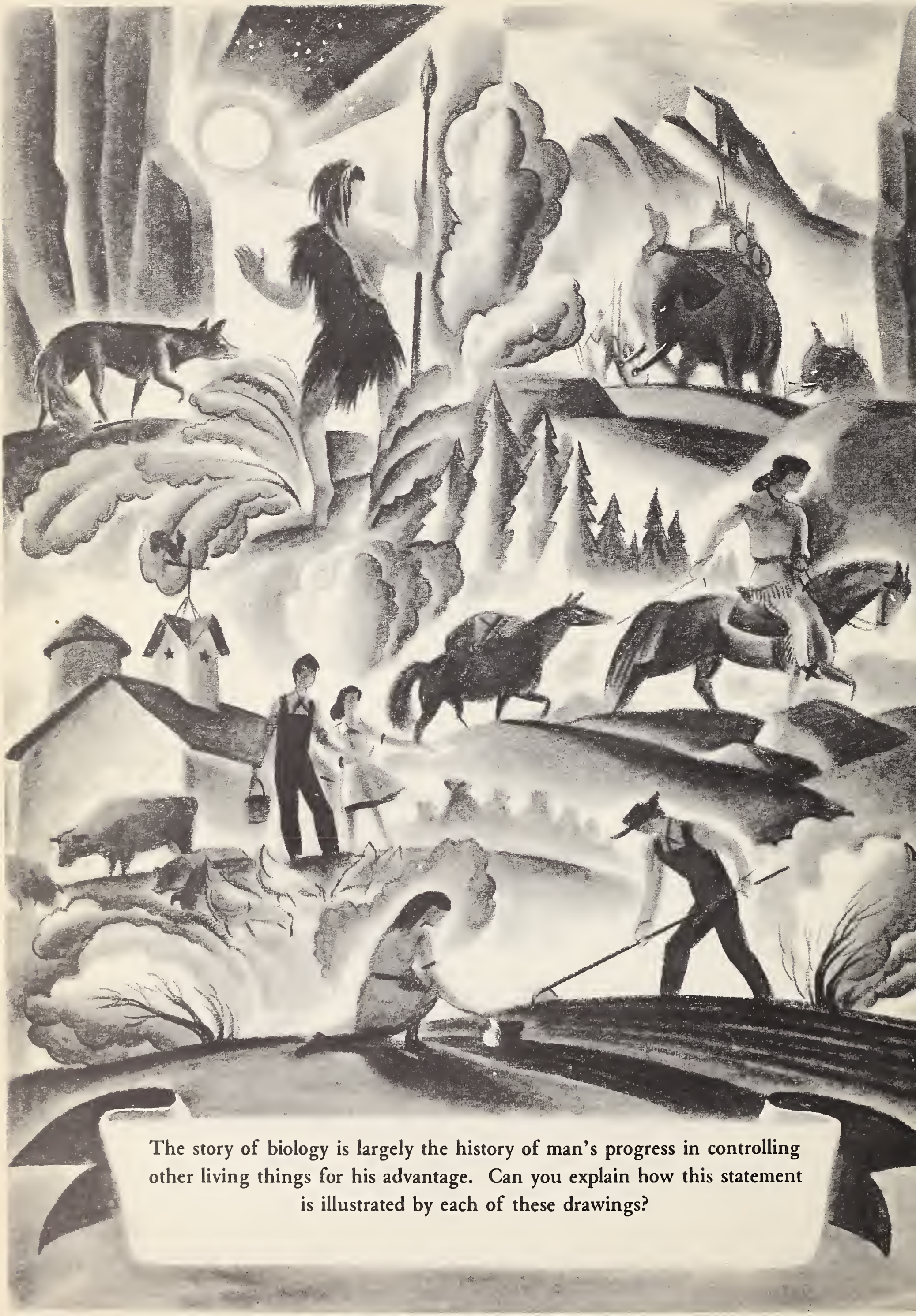
> The study of plants and animals is included in __?__.

Supplying *biology* in the blank makes the statement true.

USE THE INDEX

You will find the Index of great value not only when you want to look up the definitions of terms that are not included in the Glossary, but also when you want to review materials studied earlier or to extend and organize what you know.

BIOLOGY IN DAILY LIFE



The story of biology is largely the history of man's progress in controlling other living things for his advantage. Can you explain how this statement is illustrated by each of these drawings?

GETTING ACQUAINTED WITH BIOLOGY

One day during the Second World War, two American warships dropped anchor near the shore of a small and unimportant island in the South Pacific. Without their fighting equipment, men quickly filled the landing boats which were lowered from both vessels. The boats raced for the beach.

Scarcely waiting to reach the shore, the men tumbled out and ran yelling to a flat, grassy area a short distance from the water. There they hastily began to lay out a rectangle and to erect at each end two poles crossed by another. In a few minutes the first football field in that particular part of the world was ready for play.

A team from each vessel lined up, the officials for the game took their places, and the rest of the men hurried to crowd the side lines. The game began and continued in an uproar of enthusiasm. In the background crowds of bewildered natives watched with growing amazement, vainly trying to find out what the "crazy" white men were trying to do.

Without football suits or shoes, indeed without equipment of any sort except a football, the two teams battled up and down the rough field. Rarely, if ever, has a high-school, college, or even professional game been fought so fiercely. The furious struggle ended in a 0–0 tie. The teams, completely exhausted, and the "rooters," almost as weary, returned to their ships. All had had a wonderful time.

This incident was a practical application of biology.**[1, 2] The men would probably never have thought of it as such. Later, when discussing the game, they would probably have said, "We just challenged the other boat and played the game because everybody needed a change and some fun." But having a needed change and some fun are of great importance in maintaining good mental health. And health practices of every sort are an important part of biology.

Some years ago a high-school student was strolling along Neah-Kah-Nie beach on the Oregon coast. He noticed, at the edge of the water, a crab shell of a kind that he had never seen before. He carefully kept the shell until his return to school in the fall. Then, with the help of his biology teacher, he studied the "keys" (books) which describe the various kinds of "shell-fish" living in the ocean along the Pacific coast. He found the scientific name of the kind of crab whose shell he had picked up.

On the advice of his teacher, he sent the shell and his account of where he had found it to the department of zoology of the University of Oregon. He received a letter from the department, expressing pleasure and interest in the discovery, since that kind of crab had never before been reported farther south than Puget Sound.

The study of plants and animals to find out what kinds they are is a branch of biology (taxonomy[3]) (illustration, p. 4).

[1]*Biology* (bī ŏl′ō jĭ).

[2]You are not expected to learn all the scientific terms that are given in the text and in illustrations. They are included merely so that you may build a large scientific vocabulary if you wish to do so. The use of asterisks to indicate "essential" and "important" terms is explained in "This Book and You," p. xiii.

[3]*Taxonomy* (tăks ŏn′ō mĭ). For the pronunciation of scientific terms see the Glossary, p. 573.

Ward's Natural Science Establishme

What kinds of animals do you infer that these students are going to try to capture for study?

In Naples one of the authors of this book saw a woman bargaining with a man for some octopuses,[1] which he had caught that morning in the Bay of Naples and which she wanted for food. The man had half a dozen of the animals in a pan, which he set down in the middle of the sidewalk. Each octopus was about a foot long when its "arms" (tentacles) were stretched out. All were very much alive.

The woman was willing to buy five of them, which were yellow-brown with black spots, but did not want the sixth, which was of a lighter brown but also speckled. She put the five into her pan, and the man added the sixth, which she promptly put back into his pan. This performance was repeated at least a dozen times. Both handled the octopuses as calmly as you would handle eggs. A crowd gathered to watch and to listen to the long, loud, and vigorous discussion. Finally the woman refused to buy any at all, because the man wanted more money than she was willing to pay.

[1]Page 526. Throughout this book a reference of this sort directs you to the page where you will find an illustration, text material, or a footnote which will help to make clear the term or the topic indicated.

This incident is another example of biology. The study of foods and how living things secure and use them makes up several important branches of biology.

It would be strange if, when you looked

at the illustration on this page, you did not ask, "What is it?" It is a two-headed trout, which was given the amusing name of "Cuthbert the Great." *Science News Letter* for February 10, 1940, gives this account of it:

"Cuthbert the Great" began his career as a tiny, two-headed embryo[1] fish in the Mount Shasta Fish Hatchery in California. Two-headed embryos are fairly frequent in hatcheries, but none ever survive under natural conditions. That Cuthbert lived to adult trouthood was due entirely to the care lavished upon him by a member of the hatchery staff, Elvin C. Anderson, who adopted him as an infant and brought him up "by hand."

Having two wide mouths to eat with and only one stomach to feed, pampered Cuthbert naturally grew very fat. "By the time he was five years old, Cuthbert was the fattest fish I ever saw," stated Dr. E. W. Gudger of the American Museum staff. "He even had a ring, or groove, in each of his two back-of-the-neck regions, such as one finds on the neck of a fat man."

Cuthbert finally attained a length of eight inches and a girth of seven, and he weighed eight ounces. He lived to be seven years old, a ripe old age for a trout.

Unusual organisms,**[2] such as this one, are studied as one aspect of reproduction. Reproduction is another important area of biology.

Köhler, a German scientist, who spent many years in studying the habits of the higher apes, describes this experiment, which he carried out with one of his chimpanzees: He gave the chimpanzee two bamboo sticks of about the same length, one small enough to be pushed into either end of the other. This animal had learned long before to use a stick for pulling things within its reach. While the chimpanzee watched, Köhler put

Science Service

Cuthbert the Great is now a preserved specimen in the American Museum of Natural History. Strange organisms such as this are discussed later in this book. By examining the table of contents can you decide in which unit you will be likely to find such "freaks" discussed?

a banana outside the cage and just too far for the ape to be able to reach it with one of the sticks.

The chimpanzee began at once to try to get the banana. He tried to reach it first with one stick and then with the other. When these efforts failed, he brought over a box to see whether it would help. In an earlier experiment he had learned to climb upon this box in order to reach a banana suspended from the top of his cage. When now he found that, instead of being useful, the box was in the way, he pushed it aside.

Next he put one stick on the ground so that it pointed toward the banana, and cautiously pushed it with the other stick until its farther end touched the fruit. In doing this he pushed the stick on the ground too far away for him to be able to get it again. Köhler handed it back to him, and as he did so, stuck his own finger into the end of the larger stick. He wanted to find out whether the chimpanzee, upon seeing him do this, would take the hint and use the idea in solving

[1]Cultivate the habit of using the Glossary and the Index for extending your knowledge and for reviewing what you have already studied.

[2]*Organism* (ôr′găn ĭzm): a plant or an animal.

Bahnsen, from Monkmeyer

What sort of biological problem do you think this boy and girl are trying to solve here? Leafing through pages 207–215 will give you a hint. At first glance one might conclude that the boy was doing all the important work. Do you think he is? Explain

his problem. But the ape did not. Instead he spent more than an hour in repeating the "trial and error" methods which had already proved unsuccessful.[1] Finally he gave up.

Later, while playing carelessly with the sticks, he happened to push the smaller one into an end of the larger one. At once he ran to the place nearest the banana and, with the double stick, pulled the fruit within reach.

This experiment of Köhler's was in the field of animal behavior. Behavior—that is, the ways in which plants and animals carry on their activities—is yet another important branch of biology.

WHAT BIOLOGY IS · Five entirely different incidents have just been described, each of which related definitely to some area of biology. More than enough other incidents to fill many books could be told which would likewise bear upon these or other branches of biology. The natural question is, therefore, "What is biology?"

E[2]Biology is the study of life (illustration, p. 6). The name *biology* is made up of two Greek words, *bios*, meaning "life," and *logos* meaning "knowledge." Thus *biology* means "life science." A biologist**[3] is therefore a scientist who studies the characteristics, activities, bodily processes, history, or other aspects of living things. Strangely enough, the word *biology* was invented independently at about the same time by two noted biologists, Treviranus,[4] a German naturalist,[5] and Lamarck,[6] a French zoologist.[7]

EWHAT BIOLOGY INCLUDES · Biology deals with every kind of organism that lives or ever lived on the earth. There are believed to be at least a million kinds of plants and animals now living. Probably the number of those that lived in past ages, but that no longer do, is even greater.

Biology includes the study, not only of things that are recognized as being clearly plants or animals, but also of certain ones that are "border line" creatures. These are so called because they are in some ways like animals, and in others like plants. At present they are not regarded as being, or as likely to be, of much importance to man. But it is always possible in biology that further study of any living thing may change our ideas about it, as it has changed our ideas about many other living things in the past.

Biology includes also the study of some "border line" bodies of a different kind. Rather recently these have been discovered to have an important bearing upon human welfare. They are certain disease germs that in some ways resemble things that are alive and in others resemble non-living matter.

EBiology includes the study of all life, from a one-hundred-and-fifty-ton whale to a disease germ too small to be seen except with an electron microscope.[8]

Probably you will find of greatest interest and importance to you the relations of plants and animals to their surroundings and to other living things, especially man.[9]

[1]"This Book and You," p. xiii (*Un*, *dis*, etc.).

[2]Paragraphs in the text and in legends under illustrations, marked with the symbol E, contain especially important material.

[3]*Biologist* (bī ŏl′ō jĭst).

[4]*Treviranus* (trā vē rä′nŏŏs). Lived, 1776–1837.

[5]*Naturalist* (năt͜ ū răl ĭst): a biologist who studies plants and animals in their natural surroundings. The results of studies by naturalists make up the science of natural history.

[6]*Lamarck* (lä märk′). Lived, 1744–1829.

[7]*Zoologist* (zō ŏl′ō jĭst): a biologist who makes a special study of animal life, and a *botanist* (bŏt′*à* nĭst) one who makes a special study of plants.

[8]Page 404.

[9]The ways in which living things are affected by the life activities of other living things and by their surroundings make up the aspect of biology known as *ecology* (ē kŏl′ō jĭ). For an example of ecology, see the story under No. 8 on page 31.

Callings of which the study of biology either must be or should be the basis. Can yo
on page 12, that demand a biological knowledge? Did you ever try to suggest a

name others, besides those pictured here or mentioned in the legend of the illustration
idea with a simple drawing like these? Try it with another vocation involving biology

VOCATIONAL VALUES OF BIOLOGY · Questions that you might now ask are these: "Does biology help anybody to make a living? Are there any professions that I couldn't get into without studying biology?" The answers to these questions are given in part on pages 8 and 9. The study of biology is demanded for all the professions suggested there, such as those of physician and paleontologist.[1] It is highly desirable, moreover, as preparation for all the other callings, such as those of housewife and farmer, which are not ordinarily regarded as professions.

EVERYDAY VALUES OF BIOLOGY · Everybody is constantly learning and making use of biology almost from the beginning to the end of his life. Nobody would be likely to live long if he failed to learn how to apply biological knowledge effectively, that is, in ways that bring desired results. Biology is more or less closely related to everything that a person does (illustration, p. 11).

These statements do not mean that because everybody is constantly making use of biological knowledge, he knows that he is doing so and carefully plans how to do so. The earliest people on the earth made practical and effective uses of biology many thousands of years before anybody ever heard of the subject. Most people gain a working knowledge of biology, not from studying it as a subject in school, but through experience or through being taught by parents and others. From these sources they acquire necessary biological knowledge —what can safely be eaten as food, how to keep warm, how to get along with other people, how to keep clean, what to do when one meets a vicious dog, what to do in cases of sickness or accident, and innumerable others.

The person who has *studied* biology, however, has a great advantage over those who have not, because he knows so much more about living things and how to use this knowledge. Biology is one of the most practical subjects that you can study. It is also a source of many pleasant leisure-time activities (illustration, p. 13). The more biology you know and can effectively apply, the more successfully you should be able to live. Not only will a knowledge of this subject help you in solving your own problems, but it will give you a better understanding of national and world problems.

Checking What You Know

BIOLOGICAL TERMS · (See "This Book and You," pp. xiii–xiv.) Can you correctly spell, pronounce, define, and use each of the following terms? Consult the Glossary (p. 573) when ever necessary.

**biologist **biology **botany **zoology

Applying and Extending What You Know

APPLYING YOUR KNOWLEDGE OF BIOLOGY · 1. Perhaps you have never realized the extent to which biology is involved in your daily life. Here are some common and often-repeated experiences that involve biology. Explain how each experience is related to that subject.

Watering the lawn or garden
Washing your hands and face
Eating breakfast and other meals
Feeding your dog, cat, or other pet

[1]*Paleontologist* (pā lē ŏn tŏl′ō jĭst).

Can you explain how biology is involved in each of these activities?
Can you explain how biology is related to practicing
with a musical instrument or to mowing a lawn?

2. The illustrations on page 13 indicate that many high-school students have hobbies in which they use biological knowledge. Try to explain how a use of such knowledge is involved in the following hobbies:

Collecting moths, butterflies, or other insects
Growing vegetables — Making a rock garden
Landscape-painting — Fishing
Keeping an aquarium
Raising rabbits, pigeons, or poultry

Add to this list other hobbies which involve a knowledge of biology. Explain how this knowledge is used, or how it might be helpful.

BULLETIN-BOARD DISPLAY · Biology is a major division of science, with many branches. Several of these, including botany, zoology, taxonomy, and paleontology, have been introduced into this chapter. There are many more. Find the names of as many as you can, in textbooks of biology, dictionaries, and other sources. Make a bulletin-board display of the names, pronunciations, and definitions of the various branches of biology.

BOOKS FOR LEISURE READING

Beebe, William. *The Book of the Naturalists.* Alfred A. Knopf.

de Kruif, Paul. *Hunger Fighters.* Harcourt, Brace and Company.

Ditmars, R. L. *Thrills of a Naturalist's Quest.* The Macmillan Company.

Fenton, C. L. *Our Living World.* Doubleday & Company, Inc.

Mann, Lucile. *From Jungle to Zoo.* Dodd, Mead & Company.

Rourke, Constance. *Audubon.* Harcourt, Brace and Company.

Sanderson, Ivan. *Animal Treasure.* The Viking Press.

von Hagen, V. W. *South America Called Them.* Alfred A. Knopf.

Commercial sword-fishermen off the coast of Nova Scotia · The materials on pages 8–10 indicate that a knowledge of biology is important in many vocations. Here is a further brief list of such vocations. Select one or more that interest you and find out in what ways a knowledge of biology is important in each. Vocations: commercial fisherman, wild-animal trainer, athletic coach, manager of a restaurant, tea-and-coffee taster, life-guard, and zoo-keeper

Robe

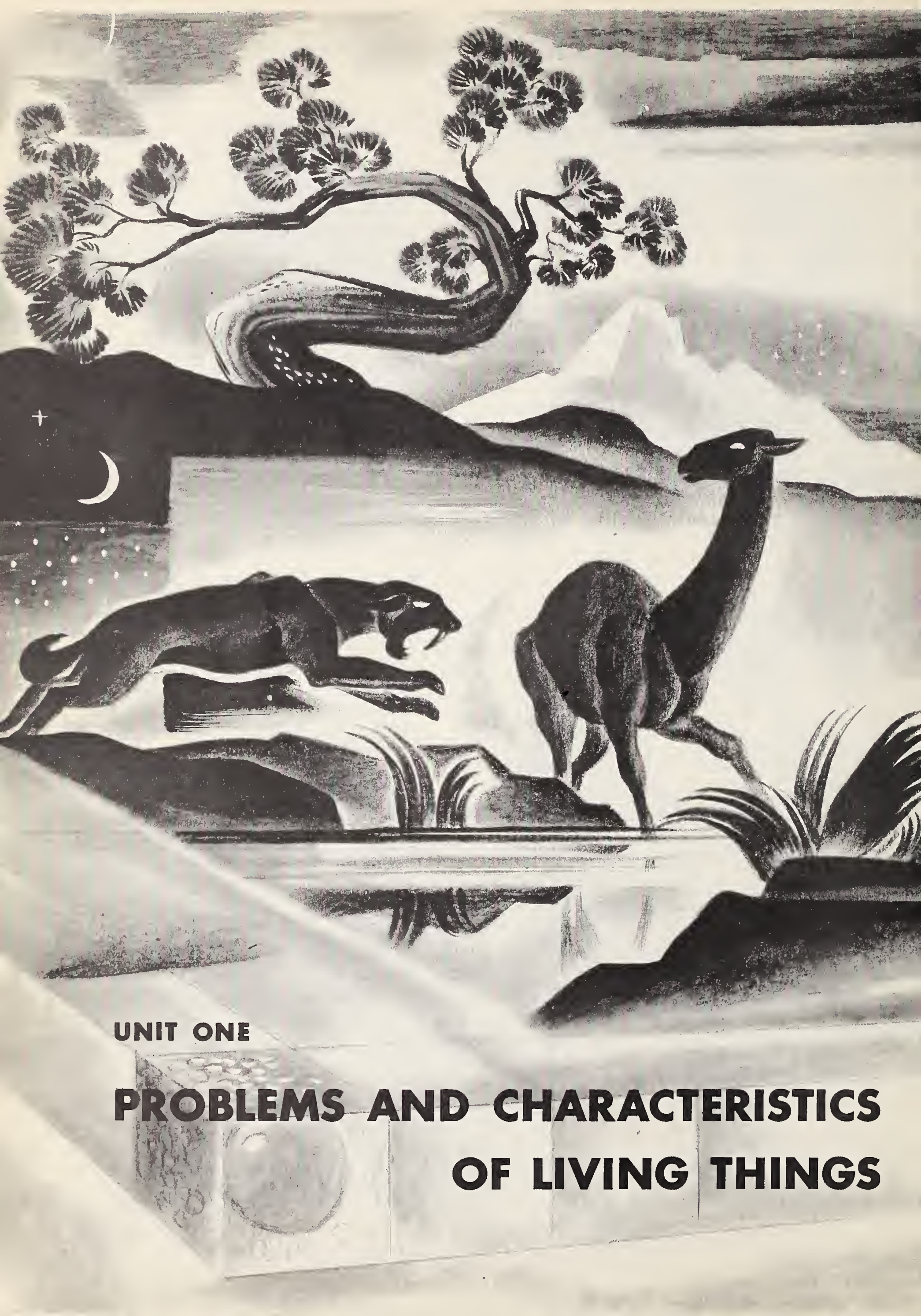
Studying birds

Mounting skeletons

Studying mushrooms

Hunting with a camera

One of the major values of studying biology is the opportunities it gives for pursuing a hobby. Can you explain how each of the hobbies illustrated here is related to biology?



UNIT ONE

PROBLEMS AND CHARACTERISTICS OF LIVING THINGS

Where are living things found?
Why do populations of plants and animals change?
What are living things like?
How are living things grouped and named?

Life is distributed in space · For what reason or reasons do you think that the particular animals shown here and on page 18 were selected for these illustrations?

1

THE CHANGING POPULATIONS OF LIVING THINGS

1. Where Are Living Things Found?[1]

On December 27, 1831, the British warship *Beagle* left England on a voyage around the world. The purpose of this voyage was scientific. It was to survey various parts of South America and some of the Pacific islands and to make measurements needed for navigation across the great oceans. Charles Darwin,[2] then only twenty-two, was already so well known as a scientist that he was appointed as the naturalist to accompany the expedition.

The voyage lasted more than four years. During this time Darwin made careful observations and records not only of the natural history but also of the geology[3] of the lands which the *Beagle* visited. Later he published an extensive account of his discoveries in a fascinating book, *The Voyage of the Beagle*, which is universally regarded as a scientific classic.

A SCIENTIST AT WORK · One of the tasks that Darwin performed was to find and classify the plants and animals that lived on the island of St. Paul. This island is merely a bare rock. It is the top of a mountain that rises out of the Atlantic Ocean almost on the equator and about five hundred miles from the coast of Brazil. It is less than three quarters of a mile around, and its highest point is only about fifty feet above the surface of the ocean.

The following quotation is from *The Voyage of the Beagle*:

> We found on St. Paul's only two kinds of birds—the booby and the noddy. The former is a species of gannet, and the latter a tern. Both are of a tame and stupid disposition, and are so unaccustomed to visitors, that I could have killed any number of them with my geological hammer. The booby lays her eggs on the bare rock; but the tern makes a very simple nest with seaweed. By the side of many of these nests a small flying-fish was placed; which, I suppose, had been brought by the male bird for its partner. It was amusing to watch how quickly a large and active crab (*Graspus*), which inhabits the crevices of the rock, stole the fish from the side of the nest, as soon as we had disturbed the parent birds. Sir W. Symonds, one of the few persons who have landed here, informs me that he saw the crabs dragging even the young birds out of their nests, and devouring them. Not a single plant, not even a lichen, grows on this islet; yet it is inhabited by several insects and spiders. The following list completes, I believe, the terrestrial fauna [land animals]: a fly (*Olfersia*) living on the booby, and a tick

[1] "Checking What You Know" (pp. 35–37) provides you with a means of finding out how well you know the material before, as well as after, studying it ("This Book and You," pp. xiv–xv).

[2] Lived, 1809–1882.

[3] *Geology* (jē ŏl′ō jĭ): the study of the history of the earth as revealed by rock formations.

Life is distributed in space · How many reasons can you think of that might account for the differences in plant and animal life in different parts of the earth?

which must have come here as a parasite[1] on the birds; a small brown moth, belonging to a genus that feeds on feathers; a beetle (*Quedius*) and a wood louse from beneath the dung; and lastly, numerous spiders, which I suppose prey on these small attendants and scavengers[2] of the waterfowl.

LIFE IS DISTRIBUTED IN SPACE · The variety of living things on the island of St. Paul was not large. But this is not strange. Not many kinds of living things could continue to survive (keep alive) on a barren rock far out in the ocean. Only a relatively few kinds would be able to satisfy their life needs and thus be able successfully to carry on their struggle for existence in such a habitat.**[3] There are few areas of the earth's surface, however, where there is no plant or animal life (illustrations, pp. 16 and 18). Yet there are vast portions of the earth as a whole where there are no living things of any kinds. The earth as a whole includes not only the solid part and the oceans and other bodies of water, but also the atmosphere.

The uninhabited portions of the earth include (1) most of the solid part, (2) the deepest parts of the ocean, and (3) the upper atmosphere. The vast numbers of plants and animals that live in the soil are found, for the most part, within a few feet of the surface. No fish or other animals are known to live at ocean depths much greater than four miles, and no ocean plants have been discovered at depths nearly so great as that. Most of the ocean life, in fact, is found within a few hundred feet of the surface.

Certain great birds, as well as man, commonly fly into the stratosphere[4] and some microscopic**[5] plants and animals have been found in samples of air taken in the stratosphere by aviators. Most birds, insects, and other organisms that fly or float in the air, however, are found less than three miles above sea level.

ᴱFrom the facts just stated it is evident that most living things can exist in only a limited part of the entire earth. This part, or layer, includes all but scattered areas of the earth's surface; yet it extends only a few miles above and below sea level. Outside this layer (biosphere[6]), no plant or animal is able to satisfy its life needs.

LIFE IS DISTRIBUTED IN LATITUDE · The illustrations on pages 16 and 18 both present evidence that the kinds of living things change as the latitude, or distance north or south of the equator, changes. For example, the plants and animals of the tropical regions are different from those of the Temperate Zones. These in turn are different from those that live in the polar regions.

Biologists have pieced together what they

[1] *Parasite*** (păr′*ȧ* sīt): a plant or an animal that lives upon or inside the body of another plant or animal and that gets all or part of its food from the other. The plant or animal upon which, or inside which, another organism lives is called a *host*.** Two important scientific terms related to *parasite* are *parasitic*** (păr *ȧ* sĭt′ĭk), caused by a parasite or parasites; and *parasitism** (păr′*ȧ* sīt ĭz'm), state of being a parasite.

[2] *Scavenger* (skăv′ĕn jẽr): a plant or an animal that eats decaying plant and animal materials, or refuse (rĕf′ūs).

[3] *Habitat* (hăb′ĭ tăt): the location and the environment** (ĕn vī′rŭn mĕnt), or surroundings, in which a plant or an animal lives. The habitat includes such factors that affect the organism's life and development as climate, soil conditions, other living things about it, land formations, and abundance of water.

[4] *Stratosphere* (strā′tō sfēr): the part of the atmosphere which begins at varying heights, from six to eleven miles, above the earth. It is the region above the clouds, rain, frost, and snow.

[5] *Microscopic* (mī krō skŏp′ĭk): too small to be seen except through a microscope**; not visible to the naked eye.

[6] *Biosphere* (bī′ō sfēr).

Life is distributed in time · Many flowering plants bloom in the spring and die before the summer plants of the same locality bloom. Many summer-flowering plants, likewise, give place to those of the fall. Can you give an original example to illustrate each of the two following biological principles? Life is distributed in space, and life is distributed in time. Life is distributed in latitude and life is distributed in altitude are both aspects of life is distributed in space. Explain. Can you explain why some plants which live only one season in Canada will live several years in the southern United States?

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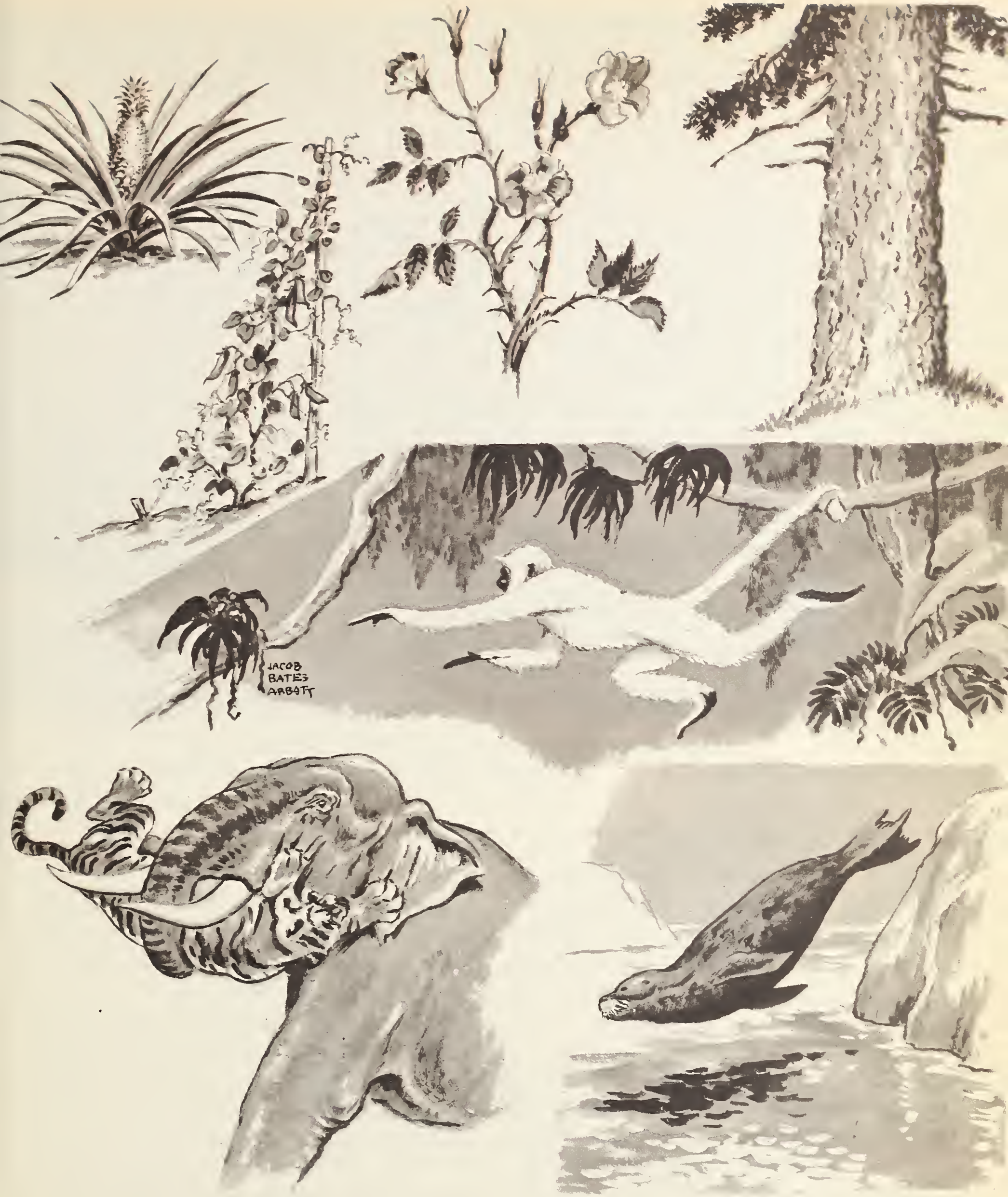
have learned about the organisms that occupy different latitudes. They have found that, in general, there is a changing "procession" of different kinds of living things as the distance from the equator is increased. There are, of course, many exceptions to this statement. Also, there is much "over-lapping" of different kinds of organisms within the different zones.

The reason for this changing procession of plants and animals is this: The farther away from the equator a locality is, the colder its climate is likely to be. The kinds of plants and animals that live in different latitudes must therefore differ from one another because each can live only where the climate is favorable to its existence.

LIFE IS DISTRIBUTED IN ALTITUDE · It has been found that changes in altitude, or height above sea level, bring changes in plant and animal life similar to those caused by differences in latitude. In a climb from the one-thousand-foot level to a higher one on a mountain-side you would see the same changes in plant and animal life as if you traveled two hundred miles, or three degrees of latitude, north-ward or south-ward from the equator.

These facts are illustrated by the living things that are found at different altitudes on the San Francisco Mountains in Arizona. At the bottom are desert plants and animals of the kinds that live in the deserts around the mountain. If you were to climb the mountain-side to about the 8000-foot level, you would, as you went upward, see changes in the kinds of organisms such as you would observe while traveling from the southern to the northern United States. From about the 8200-foot level to the 9500-foot level, you would find plants and animals such as live in southern Canada. In the zone between the



Only those kinds of plants and animals continue to survive in any environment that have the right kinds of adaptations for life there. Which of the adaptations shown here are protective adaptations? Can you think of other examples of adaptations?

These kinds of animals lived in North America about twenty thousand years
to become extinct,[1] that is, to die out completely? The various
make up what is called

9500-foot level and the 11,500-foot level, you would see organisms much like those that inhabit northern Canada. Still higher on the mountain you would discover living things that are adapted to an arctic or an antarctic climate.

LIFE IS DISTRIBUTED IN TIME · [E]Not only are living things found in some places and not in others, but also they are found in a given locality at some times and not at other times. Plant-and-animal societies[2] change both from season to season and over longer periods of time. Thus many common birds that live around our homes in the spring and summer go to warmer, distant habitats in the fall, only to return again in the following spring (illustration, p. 26).

Changes in plant-and-animal societies over longer periods are likewise a common occurrence. Have you observed how a garden plot or a grain-field changes if it is not kept in cultivation? From the start the weeds share the habitat with the desirable plants, but the weeds rapidly become the more numerous. After a few years it may be difficult to find descendants of the food plants in the society that then occupies the former garden or fields.

[1]*Extinct* (ĕks tĭngkt′).

[2]A plant-and-animal society is composed of all the plants and animals living in any one habitat.

ıgo. How many reasons can you think of that might explain how they happened ‹inds of plants and animals that live one after another in a habitat ı *biological succession*

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After a forest fire has destroyed a stand of evergreen trees, at first there are no plants on the burned-over area. Then small plants begin to cover it. Later, bushes and young trees of various sorts make their appearance. One set of plants follows another. Young evergreens appear in increasing numbers. After many years the evergreens crowd out most of the other plants, and the former stand of evergreens is finally replaced with a new one.

The changes in plant and animal life that take place during thousands of years are still more striking. The atmosphere and the earth's surface are both slowly but constantly changing. Therefore plants and animals must change, too, in order to survive. Such changes of living things are called adaptations.**[1] By "adaptations" is meant the changes, or modifications, in bodily structures and habits which fit a plant or an animal to live in a habitat. Thus heavy fur is a favorable adaptation for living in a cold climate. Rapid plant growth is an adaptation for life in a locality (place) having a short growing season. Fish scales, your fingernails, and cat's claws, all three of which are modified skin structures, and thorns, which are modified leaves, are further examples of adaptations that help organisms to survive (illustration, p. 21).

[1] *Adaptation* (ăd ăp tā'shŭn).

Whenever a habitat changes faster than the plants and animals can adapt themselves, or change, so as to continue to be able to live in it, the plants die. The animals die, too, unless they are able to leave the old habitat and find a more suitable one (illustration, pp. 22 and 23).

SPREADING TO NEW HABITATS · The life needs of organisms vary greatly. Some kinds are able to survive under widely different conditions. These become in time members of plant-and-animal societies in many localities. Thus bacteria and man have spread from wherever they first appeared to practically all parts of the world (illustration, p. 31). Other organisms can satisfy all their life needs in only a few habitats or, in rare cases, perhaps, in only one. Thus some of the rarest orchids grow only in certain relatively small areas of the tropical jungles. The Torrey pine has never been found growing anywhere except on a strip of land eight miles long and two miles wide near San Diego, California. The sidewinder rattlesnake is found nowhere except in certain deserts of the southwestern United States.

It is unusual for a plant or an animal to be found only in the locality where it is believed to have first appeared. Living things tend to spread from their native habitats to others. If they are able to survive in a new habitat, they become members of the plant-and-animal society already there. Thus the house cat, which is believed to have first appeared in northern Africa, has spread from its original home and has succeeded in establishing itself in almost every part of the earth where man can live. The peanut, which is believed to be a native of central South America, is a food crop in many parts of the earth.

Man helps organisms that are of use to him to spread to new regions. As a result, most of the fruits and vegetables that we grow for food originated in other parts of the world and have been introduced here.

Few kinds of organisms are likely to be living in all the parts of the earth where they could possibly survive. The reason why they are not is (1) that they have not yet happened to reach those places by chance or (2) that they have not yet been introduced there by man. There are no snakes in the Hawaiian Islands, though there is every reason to believe that snakes in great number and variety *could* thrive there. In former times there were no mosquitoes on the Hawaiian Islands. Now, however, there are a number of varieties, which have somehow been brought there by travelers or settlers from other parts of the world.

2. *Why Do Populations of Plants and Animals Change?*

If some naturalist were now to make the same sort of study of the life on the island of St. Paul that Darwin made more than a hundred years ago, he probably would not find exactly the same kinds of inhabitants that Darwin found. Some of the kinds of animals that lived on the island when the *Beagle* visited it might no longer be there. Other kinds might have established themselves on St. Paul since Darwin made his study. Some plants too might by now have become members of the society of living things on the island.

FACTORS AFFECTING THE ABUNDANCE OF LIFE · What are some of the factors, or conditions, that cause the numbers and kinds of plants and animals in any habitat to change?

You can probably think of some of them. The following paragraphs will discuss several:

1. **The available food supply.** [P]Every plant and animal that lives in any habitat must be able to secure there the kinds of foods it needs and enough of each kind.[1] Where there is an abundance of foods of many varieties, the plant-and-animal societies are likely to be large. If, however, any source of food becomes less abundant, the numbers of living things that depend on that source become smaller, and all the plants or animals of those kinds may die.

An example of what happens when the necessary foods for a certain kind of animal are plentiful and when other conditions are favorable is supplied by the lemming (illustration below). Every few years a colony of lemmings suddenly begins to increase in

[1]Every statement so indicated ([P]) is a biological principle. A principle is a general statement that sums up many separate facts (p. 37).

The lemming is a rodent, or "gnawing animal." It is a near relative of the rat and the squirrel. It lives in the mountain highlands, above the tree line, in Norway, Greenland, and northern Canada, and on islands in the Arctic Ocean. Why do you think this picture was placed at this point in the book?

Geese migrating over the shores of Lake Michigan · Some biologists distinguish between such departures from a habitat as those of lemmings and locusts and such departures as those of wild geese and other migratory birds in the fall and spring. They call the first *emigrations*[1] because the animals do not return to their original habitats. They call the second *migrations* because the animals leave at one season of the year and return at another. Can you give other examples than those in the text of animals that emigrate and of those that migrate?

numbers very rapidly. Finally there are too many for the available supplies of reindeer moss and grasses which make up their food. Millions are then forced to leave the habitat, or migrate**[2] (illustration above).

Such great multitudes of them move down the mountain-sides and across the country that they practically carpet the ground for wide areas. About four hundred years ago Magnus, a Swedish author, wrote that so many lemmings had suddenly appeared that he thought they must have rained down from the clouds. Great flocks of predatory[3] birds and numerous other animals accompany the migration and gorge themselves on this easily captured prey. Millions of the lemmings starve. Millions more drown in crossing rivers and fiords (deep, narrow inlets from

[1]*Emigration* (ĕm ĭ grā′shŭn).

[2]*Migrate* (mī′grāt): to move from one locality to another, which is usually far distant. *Migration*** (mī grā′shŭn): act of migrating. *Migratory* (mī′grȧ tō rĭ): having to do with migration.

[3]*Predatory* (prĕd′ȧ tō rĭ). A predatory animal, or *predator** (prĕd′ȧ tẽr), is one that preys upon other living things.

the sea). Other millions are killed by diseases. But the numbers are in large part maintained because the animals continue to breed as they advance.

Finally, after a year or two, they reach the sea. But they neither pause on the shore nor turn back. Instead, they jump into the water and try to swim across. In one case a ship traveled for miles through water which was practically covered with swimming lemmings. Cod and other large fish prey upon them. One by one the rest drown. There are no survivors unless some happen to reach an island habitat similar to the one from which the migration started.

The lemmings are fairly scarce in their old habitat for a while. Within a few years, however, their numbers have again increased so greatly that another migration takes place.

Locusts furnish other examples of what happens when the food supply no longer supports the population and when part of the population is able to migrate. There is an account of a locust "plague" in the Bible, and similar "plagues" occurred in Jerusalem and its vicinity in January, 1947. Migrations of these insects are, in fact, fairly common in many parts of the earth. In every such case the insects devour all the leaves of every crop plant, every tree, and every other plant in their path, and have been known even to eat cloth.

What happens to any kind of animal in an animal society when its customary food supply becomes insufficient and when the animals cannot leave the habitat is illustrated by the following account of the koala (illustrated here): This animal eats only one kind of food, the leaves of the manna-gum, or eucalyptus, tree. A few years ago, for some unknown reason, these trees in the sanctuary[1] lost most of their leaves. As a result, the koalas were starving. They would have been exterminated[2] if they had not been removed to another spot, where the manna-gum trees were in full foliage.

2. Temperature conditions. Plants and animals can survive in only a limited range of temperature. Many kinds of living things

[1]*Sanctuary* (săngk'tū ĕr ĭ): an area set aside as a natural home for wild plants and animals. Here they are protected by law from hunters and others who might interfere with their ways of life.

[2]*Exterminate* (ĕks tûr'mĭ nāt): to kill all of any kind of plant or animal. *Extermination* (ĕks tûr mĭ-nā'shŭn): the complete destruction of one or more kinds of living things.

The koala is commonly known as the "Teddy bear," but it is not a bear. Instead, it is a relative of the kangaroo and the American opossum. An island off the coast of Australia has been set aside as a sanctuary for the koala. What do you think might have been some reasons why that particular spot was thus selected?

International

cannot survive in certain parts of the earth, because these regions are too warm or too cold for them. [P]The lowest forms of life can, in general, endure a far wider range of temperature than the higher ones. Some of the bacteria, for example, could keep alive even though the temperature were to vary from near that of boiling water to many degrees below the freezing point of water. In contrast, the fish in the depths of the ocean live at temperatures which always remain at about the freezing point of water.

Several winters ago a sudden, unusual drop in temperature killed most of the walnut trees in certain sections of Oregon. Farmers and gardeners know from experience that continued cold weather during the growing season greatly reduces the numbers of crop plants that will grow. They know also that flies, grasshoppers, and other insect pests increase in numbers enormously during a long hot spell.

3. The abundance of water. Fish, tadpoles, the larvae**[1] of certain insects, and many other animals, as well as seaweeds and many fresh-water plants, can survive only in water. In contrast, desert plants and animals live their lives far from bodies of water. [P]Yet every living thing, no matter where it lives, must be able to secure the amount of water it needs for the kind of life it must lead.

The plant-and-animal population in any land habitat is affected by the amount of rainfall. You have no doubt often observed, during an unusually dry summer, that the grass in the lawn becomes brown and that some of it dies unless it is supplied with the water it must have. Fly larvae die if the manure or other rotting material in which they are developing dries out completely.

4. The condition of the water. The aquatic**[2] population, namely, the population made up of plants and animals that live in water, is affected by the condition of the water, that is, by whether the water (1) is flowing or stagnant (without current); (2) is cold or warm; (3) is clear or muddy; (4) is salty or fresh. Thus the kinds of fishes at the mouths of rivers that empty into the ocean change more or less as the tides change. Some marine fish follow the ocean water into the river mouths when the tide is "coming in" (flooding) and go out again beyond the river mouths to avoid the fresh water when the tide is "going out" (ebbing).

Trout seek swift, cold, clear mountain streams, where carp would soon die. Carp thrive in warm, muddy rivers and in ponds that are foul from lack of current, where trout could not long survive.

5. The amount of oxygen present. Oxygen is one of the colorless gases of the air. It makes up about one fifth of the atmosphere. [P]With the exception of a relatively small number of simple plants, all living things must have constant supplies of oxygen.

One reason why more plants and animals do not live at high altitudes is that they cannot secure enough oxygen for their needs in the thinner upper air. Man is able to fly several miles above the earth only because he is able to carry a supply of oxygen with him. The race of Indians who have lived for many hundreds of years high up in the Andes Mountains of South America, where they have had to breathe in more air at a time than we do in order to secure enough oxygen, have developed bigger chest expansions than we have.

[1]*Larva* (lär′vȧ); plural, *larvae* (lär′vē): the first stage, beyond the egg, of certain animals that go through a series of stages of development from egg to adult.

[2]*Aquatic* (ȧ kwăt′ĭk): growing or living in or frequenting water or some other liquid, such as blood or milk, which is mostly water.

Which of the factors that affect the abundance of life were likely to prove of great importance to these people and their animals?[1]

The bubbles that one sees on the inside surfaces of a tumbler of water that has stood for a while in a warm room are air that was dissolved in the water when it was colder. Water plants, fishes, and many other aquatic organisms secure the oxygen they need from the air that is dissolved in the water.

The facts just stated are related to a situation that developed during the Second World War. Because of the pressing need for their products, many industrial concerns were permitted to empty their organic**[2] waste products directly into streams, a practice which would not have been allowed in peacetime. In some cases these waste products were suitable food for bacteria[3] and other micro-organisms*[4] living in the water. This abundance of food caused an enormous increase in the numbers of these organisms. They used up so much of the oxygen in the water that there was not enough oxygen left for the fish to breathe. Consequently the fish in those streams were practically exterminated.

The amount of oxygen near the earth's surface may change enough to affect the animal population. For example, in some parts of the tropical ocean one kind of simple plant that is red in color sometimes becomes so abundant that it makes many square miles of the ocean look like blood. Such enormous

[1]From J. G. Masters, *Stories of the Far West.*

[2]*Organic* (ôr găn′ĭk): biologists define *organic* as pertaining to organisms, or living things. Plants and animals and their products (for example, milk and fruits) are composed of organic materials. Every organic substance contains carbon. Biologists define *inorganic*** (ĭn ôr găn′ĭk) matter as material, such as rock or air, that is neither alive nor the product of a living thing. Chemists have different definitions of *organic* and *inorganic* from those of biologists.

[3]*Bacterium* ((băk tē′rĭ ŭm); plural, *bacteria* (băk-tē′rĭ *ȧ*): a single-celled, non-green plant.

[4]*Micro-organism* (mī krō ôr′găn ĭzm): a plant or an animal too small to be seen except with a microscope, or perhaps too small to be seen at all—even with an electron microscope.

Leigh, from Black Star

Often, in tropical jungles, instead of there being "layers" of plants, practically all the space between the ground and the tree-tops is filled with plants. Each grows where the light is best suited to its needs. How do these facts illustrate the principles Environment affects living things, and All living things are constantly engaged in a struggle for existence?

numbers of these plants consume so much of the oxygen dissolved in the water as sometimes to cause the deaths of countless numbers of fish. In many fresh-water lakes, usually in spring or fall, there are certain layers near the bottom that contain no dissolved oxygen. Although there is abundant animal life in the lake, there are, of course, no fish or other animals in the parts where oxygen is lacking. Occasionally, but not often, a fish swims into one of those layers so far that it cannot swim out again soon enough to get the oxygen it needs. Hence it dies.

6. The amount of light. If you are familiar with the mole, you know that it spends most of its life in the darkness of its under-ground burrow. The sidewinder is abroad chiefly at night because it cannot endure much direct sunlight. The larger rattlesnake that lives in the same locality will die in less than a half-hour if exposed to direct sunlight. There are organisms, such as simple plants and animals within the soil, that live in constant darkness. If the soil were dug up so that these organisms were exposed to the sunlight, probably all would be harmed, and certainly many would be killed. In contrast with these organisms, all green plants require light in order that they may make their food. Different kinds, however, require different amounts of light.

A forest in the United States or Canada is usually made up of different "layers" of vegetation. Each "layer" is made up of plants which are able to live successfully in the amount of light that strikes them. Thus at the top of an oak forest is the "roof" of oak-tree branches, with their leaves in direct sunlight. Oak trees need direct sunlight for their food-making. Below the oak-tree branches are bushes and low plants, which can thrive in dimmer light. Below these, in still deeper shade, is a layer of moss plants.

Boeing Aircraft Company

Name several kinds of organisms which you think would not be prevented by high mountains from spreading to new habitats

If any of the oak trees are removed, with the result that direct sunlight is admitted, the plants that require dim light soon die (illustration, p. 30).

7. **The presence of natural barriers.** Each kind of organism tends to expand its range until it is stopped by some barrier. One reason why Darwin found so few kinds of living things on the island of St. Paul is that the island is far out in the ocean. The ocean is a barrier which keeps most living things away from the island. Other barriers, besides oceans, that prevent the spread of living things to other habitats are plains, forests, rivers, deserts, and mountain ranges (illustration above).

8. **The addition of a plant or an animal to a society or the elimination of a plant or an animal from it.** Many years ago a light-house was built on a small island off the coast of Portugal. The keeper of the light-house made a vegetable garden. At an earlier time rabbits had in some way got on the island and had succeeded in surviving there. As the vegetables grew, the rabbits found these new plant members of the society on their island habitat welcome additions to their usual food supply. This additional food caused the rabbits to multiply rapidly.

In order to be able to have any garden at all, the keeper of the light-house brought in some cats to reduce the rabbit population. His move was successful. The cats began at once to prey upon the rabbits. Soon they had killed and eaten every one. Then the cats starved to death because they could find nothing else on the island that would serve them as food.

Thus the adding of rabbits to the society reduced the population of vegetable plants. The adding of cats decreased the rabbit population, but increased the population of vegetable plants. The extermination of the rabbits by the cats resulted in the extermination of the cats, but further increased the numbers of garden plants.

9. Diseases. When, for a period, the conditions in a habitat are especially suitable to some kind of plant or animal, that kind may increase at an enormous rate. Even though it may be attacked by increasing numbers of enemies, yet it sometimes continues to multiply rapidly. Finally a point is always reached where the individuals cannot all get enough food. Usually, when the living things are animals, such as the lemmings and the locusts, great numbers migrate before the food supply becomes exhausted. But whether they are animals that can and do migrate or plants which cannot, in every case some disease rapidly reduces their numbers.

The disease is likely to be present all the time. Many of the plants or animals die of it during the time that their total numbers are increasing so rapidly. But when the population becomes too dense, the numbers that die of the disease suddenly become excessive. So many die that, in a short time, the kind of plant or animal that was so numerous is likely to fall far below its usual population in that habitat. Some examples will make this clear.

Plagues of disease from time to time sweep through the sections of China and India where the human population is most dense, killing hundreds of thousands. Areas over-populated with animals likewise have plagues of disease. In one part of northern Ontario, in 1916, the snowshoe rabbits were almost beyond count. A year later scarcely a single one could be found. Some disease had almost exterminated them. Dense forests of young pine trees in the Rocky Mountains are attacked from time to time by a disease that leaves only a single tree here and there.

No matter how deadly a disease may be, however, there are always some animals or plants that escape it or recover from it. These increase in numbers. Consequently, in time, that kind of plant or animal may again be too numerous for its habitat. Then the cycle*[1] begins again.

BALANCE OF NATURE · The plants and animals which Darwin found on the island of St. Paul had probably established a balance of nature, or balance of life, there. This statement means that the numbers of the different kinds of living things remained about the same from year to year. How many crabs, birds, parasites, etc. there could be on the island would depend on the amount of food and other life necessities available and on the number of the enemies of each kind of living thing.

EP Every plant-and-animal society tends to establish and maintain a balance of nature. So long as the conditions in the habitat remain unchanging, the numbers of the various kinds of organisms remain about the same. The balance of nature is almost certain to be disturbed, however, (1) whenever a marked change, due to a change in climate or some other condition, occurs in the habitat or (2) whenever the membership of a society is changed either by having a new plant or animal become established in the habitat or by having an old member disappear from it (illustration, p. 33).

The reason why a change in the habitat affects the balance of nature is that such a change is certain to be favorable to some organisms and unfavorable to others. Hence the numbers of the former increase, and those of the latter decrease. For example, a farmer drained a small lake in one of his fields. Of course all the aquatic plants and animals that had lived in the lake died. Terrestrial, or land-dwelling, plants and animals soon occu-

[1] *Cycle* (sī'kl): a series of stages, or units that are repeated over and over; as, the seasons of the year or a continuous motion-picture program consisting of several films.

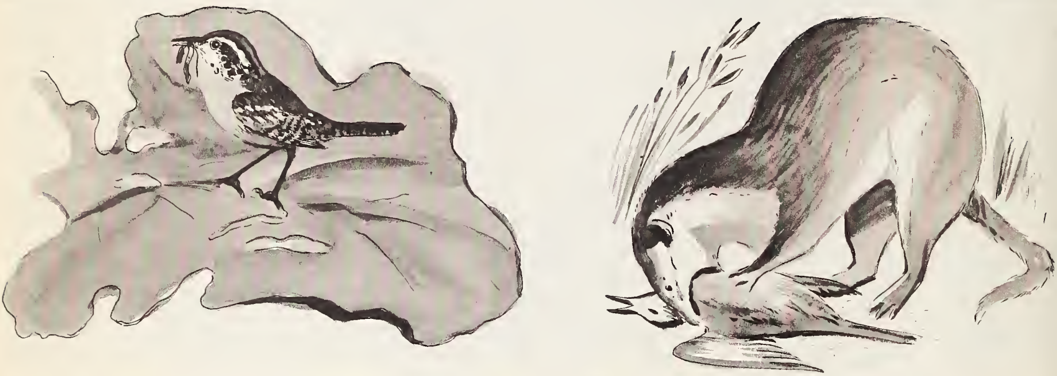
In the early days of railroading in the West, trains were sometimes stopped by herds of bison (commonly called buffaloes). Many decades have passed since such an event could have occurred. Can you explain how this picture and these statements are related to the balance of nature?

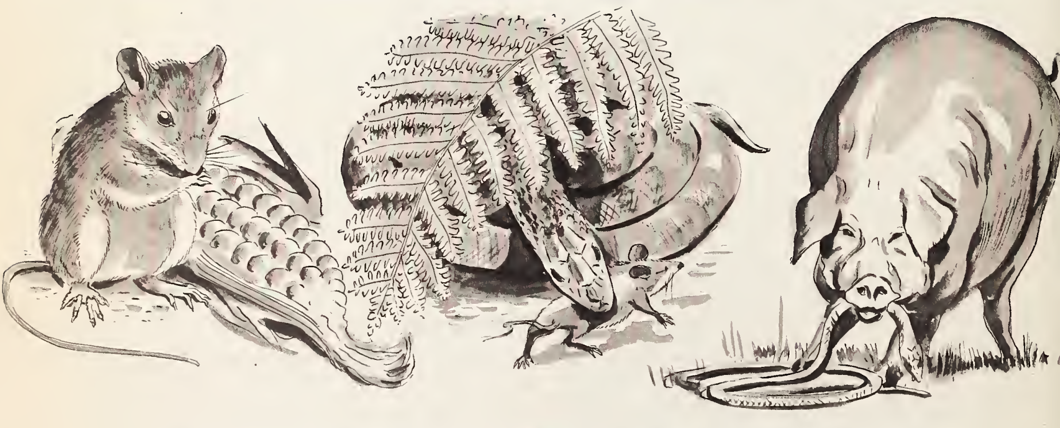
pied the former lake bed. In time the members of the changed plant-and-animal society established a new balance of nature.

[P]A change in the membership of a plant society or an animal society always affects the balance of nature. To illustrate, some years ago bass were introduced into certain Western rivers of the United States. Many people feared that these predatory fish would devour all the trout in those streams. But they did not. They reduced the population of trout considerably, but within a few years they had found their place in the balance of nature. The numbers of both bass and trout thereafter changed little.

Another example of the effects of a changing population upon the balance of nature is afforded by the story of the keeper of the light-house and his vegetable garden.[1] While the numbers of vegetable plants, rabbits, and cats were rapidly changing, no balance of nature could become established. Even after the death of the last cat the balance of nature could not be restored in the garden plot, because the man killed the weeds and decided

[1]Page 31.





Can you explain these three "food chains"[1]? How are food chains related to the balance of nature? Can you think of a food chain in which you take part? How do food chains illustrate the fifth, sixth, and eighth principles, p. 37?

[1]See "Food chains" in the Index.

how many food plants of each kind he would grow. But if later he had decided not to have a garden, the balance of nature would in time have again become established where the garden had been.

The examples given in the two preceding paragraphs show how the food-getting activities of animals may affect the balance of nature (illustration, p. 34). Life activities other than those concerned with food are likewise related to it. An illustration of this statement is supplied by four inhabitants of Arizona. These are the "giant cactus" (saguaro[1]), which is the largest cactus in the world, sometimes attaining a height of sixty feet (illustration, p. 50); two kinds of woodpeckers, the Gila[2] woodpecker and the gilded flicker; and the elf-owl, which is the smallest owl in the world, being about the size of a sparrow.

The Gila woodpecker commonly, and the gilded flicker nearly always, nest in a hole which they dig out in the stem or branch of a giant cactus. The elf-owl makes its nest chiefly in an abandoned nesting hole which one or the other of these birds made the year before or during a still earlier nesting season. Hence there is a succession—cactus, woodpecker, owl.[3]

If living enemies or changes in the habitat should exterminate the giant cactus, then the relative numbers of both kinds of woodpeckers and elf-owls might be reduced by a lack of suitable nesting places. If the woodpeckers should be exterminated, the relative numbers of elf-owls might similarly be reduced. In any case the balance of nature would be disturbed. Later, however, a new balance of nature would be established.

Checking What You Know

BIOLOGICAL FACTS · The following test items are of the Modified Multiple-Response type. This type and others used in this book are described and explained in "This Book and You," p. xv.

Pages 16–24. **1.** Vultures are birds which feed upon the flesh of dead animals. For that reason they are said to be (1) organisms; (2) parasites; (3) hosts; (4) attendants; (5) birds of prey.

2. Most of the living things in the ocean are found (1) at the bottom in the deepest places; (2) at the surface; (3) not much more than a mile below the surface; (4) in arctic waters; (5) at depths of three or more miles.

3. On the land portion of the earth, life is most abundant (1) on or near the surface; (2) along the shores of the oceans; (3) deep within the earth; (4) in mountainous regions; (5) in swampy areas.

4. When the habitat of a plant changes, that kind of plant (1) always increases in number there; (2) always becomes extinct there; (3) must change in structure and life habits or become extinct; (4) always continues as it was before; (5) migrates.

5. When the habitat of an animal changes, that kind of animal (1) always becomes extinct there; (2) continues to exist there unchanged; (3) is not affected; (4) must adapt itself to the new conditions or migrate; (5) dies in great numbers from disease.

6. An illustration of biological succession is (1) the succession of classes that go through a school; (2) the different men who have held the same job in a factory; (3) the different kinds of birds that migrate south, one after the other, in the fall; (4) the different kinds of plants that follow one another in a burned-off area; (5) the succession of English kings.

[1] *Saguaro* (sȧ gwä′rō).
[2] *Gila* (hē′lȧ).

[3] Footnote 9, p. 7 (ecology).

7. All the living things of a certain locality make up (1) the total environment; (2) a habitat; (3) an organism; (4) a population that does not change; (5) a food chain.

8. Living things have a tendency to (1) remain in their original habitats; (2) spread to new habitats; (3) spread from cold climates to warm climates; (4) spread from tropical to frigid climates; (5) spread widely across any barriers.

Pages 24–35. **9.** When food is plentiful, wild animals tend to (1) become more numerous; (2) decrease in number; (3) eat more than they can digest; (4) spread at once to new habitats; (5) remain in about the same numbers.

10. Water is needed by (1) most living things; (2) some living things; (3) plants more than by animals; (4) animals more than by plants; (5) all living things except those in deserts.

11. Oxygen is needed by (1) animals only; (2) both plants and animals; (3) plants only; (4) land life only; (5) all fish except those that live at great depths.

12. The migrations of some animals seem to be caused by (1) a scarcity of food; (2) scavengers in the habitat; (3) their restless natures; (4) an instinct of curiosity; (5) moving from one habitat to another.

13. Wherever the numbers of the different kinds of plants and animals remain relatively the same in any place for a long period, there is said to exist there (1) an emigration; (2) a sanctuary; (3) a biological succession; (4) a changing environment; (5) a balance of nature; (6) an abundant food supply.

14. Name nine factors that affect the numbers and kinds of living things in a habitat.

The "Antarctic Bus Line" in Little America during Admiral Byrd's Antarctic Expedition in 1946–1947 • Man could never have spread to all portions of the world except through his knowledge and use of science. Name several uses of biological knowledge that made possible man's existence in the locality shown here

Official United States Navy photo, from Gendrea

BIOLOGICAL PRINCIPLES · As has been indicated, a biological principle is a general statement that is true of a large or a small group of living things. Not many principles are universally true, that is, true of *all* plants and animals. Those that are include "All living things must have food" and "Every kind of plant or animal produces young." There are no exceptions to these. Hence they are major principles. But most statements of principles must be qualified, or narrowed in scope, in order to be true. For example, "All animals have eyes" is too broad to be true, because such an animal as an earthworm has no eyes. "All flowering plants grow from seeds" is likewise too broad to be true. Both these statements, therefore, must be qualified so as to take account of exceptions, thus: "*Many* animals have eyes" or "The *higher* animals have eyes"; and "*Many* flowering plants grow from seeds." These statements are minor principles. In stating scientific principles, therefore, one must be careful to use scientific caution by taking account of exceptions in order to avoid making statements of principles that are not true.

Here is a list of biological principles[1] which are stated, explained, or illustrated in the chapter that you have just studied. It is important for you to be able to explain and to give an example of each of them in your own words and, if possible, from your own knowledge and experience.

1. All life exists on or within a few miles of the surface of the earth.

2. As time passes, there is a biological succession; that is, there are changes in the kinds of plants and animals which populate any particular part of the earth.

3. Living things tend to spread from their native habitats to new places.

4. Living things affect the environment, and the environment affects living things.

5. Matter is changed from one form to another, but it can neither be created nor be destroyed.

6. Living things depend on one another in various ways.

7. Whenever a new kind of living thing settles in a habitat, it upsets to some extent the balance of life existing there.

8. All living things are constantly engaged in a struggle for existence.

BIOLOGICAL TERMS · Can you correctly spell, define, and use each of the following terms? Consult the Glossary whenever necessary.

**adaptation	**host	**organic
**aquatic	**inorganic	**organism
**environment	**microscopic	**parasite
**habitat	**migration	**terrestrial

Applying and Extending What You Know

AS SCIENTISTS WORK AND THINK · 1. In the quotation from *The Voyage of the Beagle* (pp. 17 and 19) are a number of statements that indicate the use of several of the elements of scientific method. Making observations is one of these elements. Can you point out others?

2. Which of the elements of scientific method was used in collecting the facts about the migrations of lemmings (pp. 25–27)?

3. Which of the scientific attitudes listed on page 571 are indicated by the quotation (pp. 17 and 19) from *The Voyage of the Beagle*? Pick out the sentences which illustrate these attitudes.

4. Which of the scientific attitudes did Magnus lack when he wrote that he thought the lemmings must have rained down from the clouds?

[1] "This Book and You," p. xii.

CONSUMER BIOLOGY · Below is a question, based on a discussion in the chapter, which is of special interest and value in consumer education. This chapter and others will no doubt lead you to think of other questions emphasizing consumer education. Post them on the bulletin board. Such questions provide a basis for panel discussions[1] and other discussions in class, in the home room, in the science club, or even in the assembly hall as a program to be presented before the whole school.

How do the facts about emptying wastes into streams affect the supplies of fish for food?

APPLYING YOUR KNOWLEDGE OF BIOLOGY · **1.** Why is most of the ocean life found near the surface?

2. Give one or more examples of man's upsetting the balance of nature in his attempts to control living things for his advantage.

3. Man is able to live in more different kinds of climates and conditions than most other kinds of living things. Why is this true? How does man make it possible for himself to live at the equator? at the poles of the earth? How does he adapt himself to changes in weather? How does he adapt himself to changes brought about by the changing seasons?

TOPIC FOR INDIVIDUAL STUDY · Select one or more different kinds of plants and a number of different kinds of animals and, in an encyclopedia or college textbook of zoology or other reference book, find out how they are distributed in space; that is, find out in what parts of the world they exist and in how large a territory they may be found.

WHY NOT BECOME A NATURALIST? · **1.** What evidences can you find of changes in a habitat? Visit an abandoned farm, a field, or a vacant city lot to find changes in the kinds of plants that live there. What traces, if any, can you find of cultivated plants? What evidence is there to indicate that they are being crowded out by weeds, shrubs, or young trees? What kinds of plant life do you think will take possession of the farm, field, or lot within the next ten years if it is left undisturbed? within the next fifty years? Where will these plants come from? How will they get to the field or lot?

2. Biological survey. What can you find out about some plant or animal society? If there is a pond, a lake, a small stream, or a river near your home, visit it when you have an hour or more to spend in investigating it. Or use for your study a garden, a city park, a deep woods, a farmer's field, or the margins of a road. Take a biological census by writing in a notebook the names of all the kinds of plants, or all the kinds of animals, or both, that you recognize. Include in your record the nature of the spot (dry, swampy, etc.) in which you find each living thing. If it is an animal, record what it is doing at the time that you see it. You will probably see many kinds of living things that you will not recognize. Write as careful and complete descriptions of these as you can, and later try to find out what they are. Do not expect your teacher to be able to tell you what they are. It would be reasonable to expect him to identify any considerable proportion of them only if he is a highly trained naturalist, as few biologists are.

You may later want to try to decide on the phyla to which you think the more numerous kinds of plants and animals probably belong.[2] In many cases you will not be able to be certain. Again do not expect your teacher to be able to tell you unless he is a highly trained taxonomist.

BIOLOGY IN THE NEWS · Look for reports in newspapers and news magazines on the effects of sudden temperature changes, droughts, and other weather conditions on living things. Display the reports on the bulletin board, or be prepared to discuss them in class or in the science club.

[1]Panel discussions are described on page 116.

[2]Pages 511–566.

2

CHARACTERISTICS OF ALL LIVING THINGS

1. What Are Living Things Like?[1]

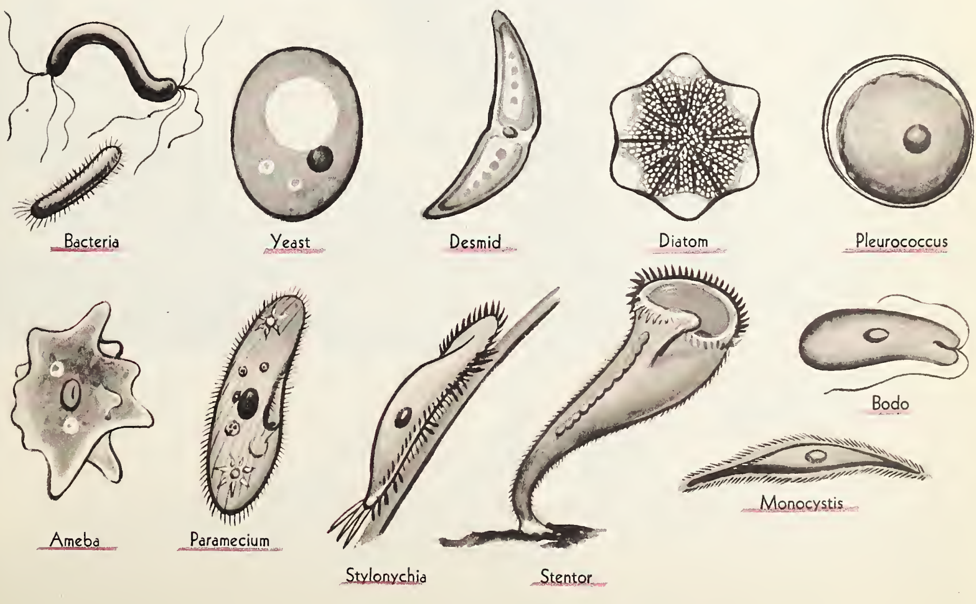
What is the largest living thing that you ever saw? Was it an elephant, a whale, or a great tree (illustration, p. 40)? What is the smallest living thing that you ever saw? Was it a very little spider or a tiny gnat or other insect? Probably it was so small that you could scarcely discern what it was. Yet if it was big enough for you to see at all with your naked eye, it was not a small organism. It was, in fact, huge, compared with millions of animals and plants that exist all about us.

LIFE IN A DROP OF WATER · By studying some minute[2] creatures you can learn impor-

[1]Footnote 1, p. 17.

[2]*Minute* (mĭ nūt′). Do not confuse this word, which means "exceedingly small," with *minute* (mĭn′ĭt), a unit of time, which is spelled in the same way.

Top row, one-celled plants; bottom row, one-celled animals · One-celled organisms are the simplest living things because the entire body of each consists of just one cell. Compare these cells by stating ways in which they are all alike and ways in which each differs from all the rest. Read your text, pp. 41–42



tant facts about all living things, both large and small. It will not be hard to get some of these animals and plants to study. Put into a jar a handful of dry grass, some decaying leaves and soil from under a tree, and, if easily obtained, a little well-rotted barn-yard manure. Fill the jar with water. If you live near a pond, put into another jar some pondweeds and some of the mud from the pond bottom. Fill this jar with water, too. Put the jars aside in a warm room. By the end of a week there should be great numbers of plants and animals in the jars.

Though it is barely possible that you may be able to see some of the small living things as moving specks in the water, you will need

Scientists believe the whale to be the largest animal that has ever lived, but the whale is small compared with the largest plant, the sequoia tree. Every living thing has a "most successful" size, from which it cannot vary too greatly and still continue to survive. What do you consider the most successful size for man? Why do you think the man was drawn standing beneath the tree at the bottom?

a microscope in order to study any of them. Prepare several microscope slides, using drops taken here and there near the surface of the water in the jars (directions, p. 60). Examine the slides with the microscope. You will doubtless see many objects darting about so rapidly that you cannot clearly discern what they look like. Some of these may be green. You will probably see also some green bodies that are not in motion.

CELLS · Most of the moving things on your slides will be one-celled, or single-celled, animals called protozoans.[1] They belong to the great group called the Protozoa.**[1] The motionless green bodies will probably be one-celled plants belonging to the group of plants called algae**[2] (illustration, p. 39). Some of the moving green bodies may be one-celled "border-line"[3] organisms, so called because in some ways they are like animals, and in other ways like plants.

^E Cells**[4] are somewhat like tiny boxes or bags of various shapes but usually oblong. When you observe them through the microscope, they look flat, but they have thickness, as well as length and breadth. They vary considerably in size, but most of them are microscopic.

^EP Every living thing, except a one-celled animal and a one-celled plant, is made up of many cells, usually many millions, often many billions. You will doubtless see on your slide some many-celled plants and animals along with the protozoans and algae. The cells that compose big organisms, such as whales and trees, are in general no bigger than those composing protozoans and algae. A whale or a tree is big not because its body is constructed of big cells, but because its body consists of billions of cells, most of which are microscopic.

PROTOPLASM · You can learn some of the characteristics of all cells by studying the protozoans on the slides. Every plant cell or animal cell is composed of a substance somewhat like watery jelly or the white of an egg. This substance is called protoplasm.**[5]

^E Protoplasm is living material. In fact, it is the only living material there is. When a plant or an animal dies, what was protoplasm before its death changes in some way that is not yet understood, so that it is no longer protoplasm. It looks the same as before, and has the same chemical composition and the same weight. Yet it is different because whatever was in it that made it alive is no longer there.

^E The protoplasm of one living thing is much the same as the protoplasm of every other living thing, yet never exactly the same. All protoplasm is alike in being composed chiefly of carbon, hydrogen, oxygen, nitrogen, and sulfur. But samples of protoplasm from different organisms, or from different parts of the same organism, are not exactly alike. The reason they are not is that they contain, in addition to the five substances just mentioned, varying quantities of phosphorus, calcium, magnesium, chlorine, and other substances. Hence cats are different from dogs, feet are different from eyes, and skin is different from muscle because the protoplasm of each is made up of somewhat different materials from those composing the protoplasm of the others.

CELL STRUCTURES · If you can get a good look at the protozoans on your slides, you will

[1] *Protozoan* (prō tō zō′ăn); *Protozoa* (prō tō zō′ȧ). Pages 513–515.

[2] *Algae* (ăl′jē); singular, *alga* (ăl′gȧ). Pages 554–557.

[3] Pages 564–566.

[4] *Cell* (sĕl).

[5] *Protoplasm* (prō′tō plăzm).

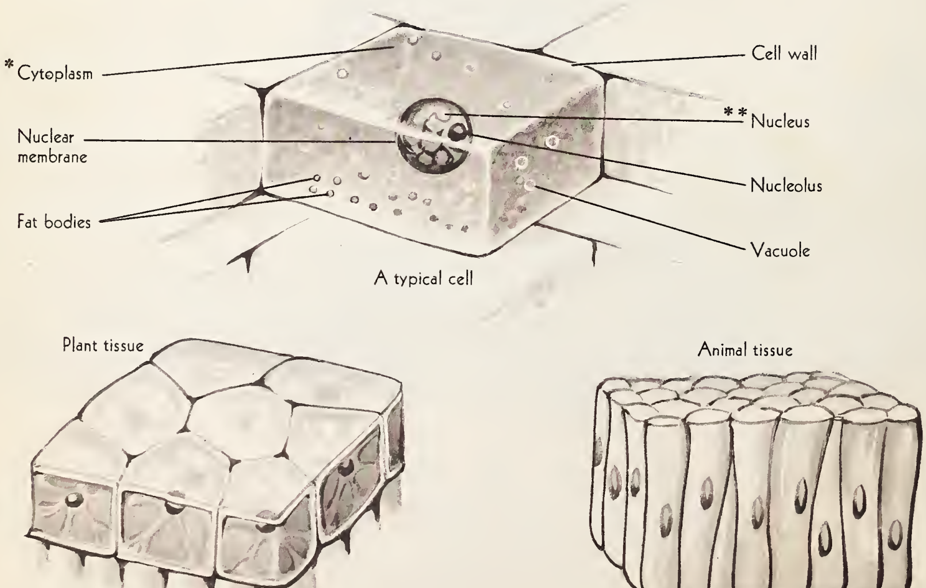
probably be able to see, inside some of them, a round, darker-colored portion of the protoplasm (illustration below). This is the nucleus.**[1] The rest of the cell contents is thinner, more watery protoplasm, called cytoplasm.*[2] Here and there in the cytoplasm you may see things that look like specks and bubbles. The specks are likely to be particles of food or bits of coloring matter, called pigment. The bubble-like objects may be tiny drops of fat, or they may be minute pockets (vacuoles[3]) of air or of watery fluid (cell sap).

[P]Every living cell is composed mostly of cytoplasm, and almost every kind of cell has a nucleus. *Paramecium*[4] differs from most cells by having two or more nuclei, commonly a large one and a much smaller one near it (illustration, p. 39). A few kinds of cells do not have definite nuclei, but such cells have the kinds of protoplasm that make up nuclei, scattered through the cytoplasm.

A typical plant cell has a cell wall, made of a woody material called cellulose.[5] The cell wall completely surrounds the cytoplasm. A typical animal cell has, instead of a cell wall, a cell membrane, composed of cytoplasm slightly denser than the rest. The cell membranes allow flesh or other animal structures to be easily changed in shape by squeez-

[1]*Nucleus* (nū′klē us); plural, *nuclei* (nū′klē ī).
[2]*Cytoplasm* (sī′tō plăzm).
[3]*Vacuole* (văk′ū ōl).
[4]*Paramecium* (păr ȧ mē′shĭ ŭm); plural, *paramecia* (păr ȧ mē′shĭ ȧ).
[5]*Cellulose* (sĕl′ū lōs).

Tell what evidence you see in these drawings which supports this principle: The cell is the unit of structure in all plants and animals. Tissues and organs are specialized structures. Explain



ing or pressure. The cell walls of plants resist pressure and hence prevent plant structures from readily changing shape.

COMBINATIONS OF CELLS · [E]All living things except the simplest ones—namely, the single-celled plants and animals—are made up of different kinds of cells. A complex organism, such as man or a flowering plant, is composed of many different kinds. Cells that are of the same kind, and that perform the same functions,**[1] are found grouped together. Such a group of cells is called a tissue.** An example of a common tissue is skin. Another is muscle tissue, which is the red meat that we buy from the butcher.

[E]Complex plants and animals are composed not only of cells and tissues, but also of organs and organ-systems, or systems. An organ** is a group of tissues that act together to perform some special function. Your hand is an organ. One of its important special functions is to seize and hold objects. The hand is composed of several different kinds of tissues, each made up of an enormous number of similar cells. These tissues include skin tissue, muscle tissue, bone tissue, nerve tissue, and connective[2] tissue, such as the ligaments that connect bones. Other common organs are eyes, hearts, wings, feet, and tongues. All living things, except single-celled plants and animals, have tissues, and all except the single-celled plants and animals and a few other simple kinds have organs.

[E]An organ-system,** or system,** is a group of organs that act together in performing some complex process or action. For example, the digestive system is an organ-system, composed of the stomach, the intestines, and the numerous other organs that take part in the digestion of food.

DIVISION OF LABOR · [E]In either a protozoan or a one-celled plant all the life functions are carried on by its single cell. In the more complex living things that have organs, however, each organ is a specialized structure which does work which no other structures can do. The performing of various functions by the different structures of a plant or an animal is called division of labor.** [P]The more complex an organism is,—that is, the more different structures it has,—the more highly specialized are its parts and hence the greater the division of labor among them (illustration, p. 44).

It will help you to understand division of labor in a cat, a person, a tree, or any other organism if you think of the division of labor that exists in your school or in an armed force. In the school the principal, the teachers, the janitor, and the pupils have their own special duties and tasks. By thus sharing the work of the school, they make it possible for the school to continue. In an armed force certain individuals man the airplanes, certain others man the war-ships, still others fight on the ground, and so on. Each has his own special functions, and the work of each affects the welfare of the whole.

SUCCESSFUL ORGANISMS · [E]Any complex plant or animal is "successful" to the extent that each of its structures does its part successfully in the division of labor. By a "successful" organism is meant one that is successful in the struggle for continued existence, or survival. In other words, an individual plant or animal is successful (1) if it can get enough food and enough of all other life necessities; (2) if it can fight off its living enemies or can keep alive in spite of their attacks; (3) if it can survive for at least its

[1]*Function* (fŭngk′shŭn): the special work or activities of a structure, or of a part of an animal or a plant.

[2]"This Book and You," p. xii.

National Dairy Products Corporatio

What organs are used in riding a bicycle? How is division of labor illustrated in riding a bicycle? The carrier on the handle-bars contains no protoplasm. Explain

normal life-time in spite of all the unfavorable conditions in its habitat; and (4) if it can live long enough to produce offspring.

ᴱThe success of a group of organisms, such as the insects, the Protozoa, or human beings, is judged by somewhat different standards from those by which the success of an individual organism is judged. A group of plants or animals is successful (1) if it has many kinds (for example, the many kinds of "cats," such as house cat, lion, tiger, panther, and lynx); (2) if it has an enormous number of individuals (for example, the dandelion and the English sparrow); (3) if its different kinds can live in a great variety of habitats all over the earth (for example, polar bears in the frozen north and various other kinds of bears in the forests of all the continents); (4) if it (an animal) can use many different kinds of things for food; and (5) if it can protect itself, or is naturally protected, well enough against its living enemies, and against unfavorable conditions in its habitat, so that it continues to live on the earth for thousands or even millions of years.

All the great groups discussed in another part of this book[1] are successful groups of organisms. Some, as would be expected, are more successful than others.

[1]Pages 511–566.

SUCCESS IN RELATION TO "FRIENDS" AND "ENEMIES" · E The words *friend* and *enemy*, which are commonly used in discussions of plants and animals, are not biological terms. Except among people and perhaps among a few of the higher mammals,[1] no living thing *tries* to help or to injure any other living thing. Every plant or animal, with the few exceptions just mentioned, carries on its own struggle for survival without considering in any way how its activities may affect any other living thing. Hence a "friend" is merely an organism whose life habits are such as to make the survival of man or some other organism easier. An "enemy" is one which, in its efforts to survive, makes man's or another organism's survival more difficult or impossible (illustration, p. 46). An animal or a plant is "important" to man only to the extent that its life habits affect his or can be made to do so.

PROTOZOA AND LIFE PROCESSES · If you examined the drops of water with the microscope, as directed earlier in this section, you knew at once that the minute things that you saw darting about were alive. The ways in which they were moving were enough to convince you that they were living things. If you should observe protozoans long enough you probably would find further evidence that they are alive. If, for example, you should be fortunate enough to find an ameba[2] on the slide, you might see it take in food by flowing around an alga or other minute body. You might see a paramecium divide into two smaller paramecia. By observing these two paramecia long enough, you would see that they grew in size until they became as large as the paramecium that had divided to produce them. If you were to put a drop of ether under the edge of a cover glass, so that it would mix with the drop of water on the slide, you would see all the moving things stop at once, as if dead.

If you were to make a thorough study of the Protozoa, you would learn that, small as thay are, they have all the characteristics that every living thing has which make it different from something that is not alive. You would learn that they carry on all the life processes that every living thing must carry on in order to maintain life. Food-getting, producing young, and other life processes will be discussed at later points in this book.

[1]Page 549.

[2]*Ameba* (*ȧ* mē'b*ȧ*).

DIFFERENCES BETWEEN PLANTS AND ANIMALS · The common kinds of plants look so different from any common kinds of animals that it would seem easy to tell from the appearance of an organism whether it is a plant or an animal. But sometimes it is not easy. In some cases it is impossible because the organism is like a plant in some ways and like an animal in others. Most plants, however, are different from most animals in these respects:

1. Plants that are partly or wholly green can make their own food, but no true animal[3] can. The green plants[4] can do this by means of the green material, chlorophyll,**[4] which they contain. No true animal contains chlorophyll.[5] Because green plants can make their own food, they are independent organisms. Animals must find plants or other ani-

[3]Page 564.

[4]*Chlorophyll* (klō'rō fĭl).

[5]Although there are a few plants (for example, some of the molds) that are green in color and yet contain no chlorophyll, the term green plant is generally used to mean "chlorophyll-bearing plant." Throughout this book therefore, the term *green plant* is used to mean a plant that contains chlorophyll, and the term *non-green plant* to mean a plant without chlorophyll.

Types of "enemies" of living things · (1) Those that kill or injure an organism; (2) those that deprive a plant or an animal of all or part of its food or other life necessity; (3) those that change the habitat so much that the former inhabitants can no longer live in it. Which of these types of enemies is shown in each of these pictures?

mals, or the products of plants or animals, which they can use as food. Hence animals are dependent organisms. There are many non-green plants, that is, plants without chlorophyll. These cannot make food. Hence they are dependent organisms, just as the animals are.

2. Most animals have locomotion,**[1] but most plants do not. Common forms of loco-

[1] *Locomotion* (lō kō mō'shŭn).

motion are crawling, walking, swimming, and flying (illustration, p. 48). Even the Protozoa possess locomotion. Some (*Paramecium* and *Monocystis*[1] swim by means of back-and-forth "rowing" motions of their cilia[2] (illustration, p. 39). Others (*Bodo*)[3] swim by lashing about with one or more whip-like flagella.*[4] Cilia and flagella are hair-like extensions of protoplasm. Other protozoans (*Ameba*) crawl upon the bottom of a pond or upon objects under water by pushing out portions of their bodies here and there and then flowing into the extended parts. Still others (*Stylonychia*)[5] crawl by using their cilia as if these were legs. Even the kinds of protozoans (*Stentor*)[6] that are attached by stalks to objects under water are able to shift about to some extent.

Most plants are anchored to one spot by roots or similar structures. Some simple green plants, however, have locomotion like that of some of the animals. For example, certain thread-like algae[7] sway and glide through the water like microscopic snakes. Scientists, however, have never been able to discover how they are able to move in this way. Some kinds of bacteria[7] swim with cilia or flagella, sometimes at the rate of one inch in about fifteen minutes. Also, some of the one-celled algae, called diatoms,[7] move rapidly through the water, and others crawl slowly on under-water surfaces by means of "false feet" somewhat like those of amebas.

3. Most animals move cilia, legs, or other parts of their bodies in ways that can readily be observed. Plants have body movements, too, but these movements are too slow to be noticed. As plants grow and as they respond to sunlight and other conditions in their habitats, they gradually change the positions of their parts. Such movements have been studied with slow-motion pictures.

4. Most plant cells have walls made chiefly of cellulose. No animal cells have walls composed of this substance.

5. Animals and plants require the same kinds of food substances, but they secure these substances in different ways. Most animals take in food in solid pieces. Plants either make their own food or absorb it in liquid form.

6. No plants have muscles and nerves. All the animals, except very simple ones, have true muscular and nervous systems.

7. The individual plants of a kind usually vary more widely in structures than do the individual animals of a kind. For example, all the apple trees in an orchard will have different numbers and arrangements of branches and roots, but all the cattle on the range will have the same numbers of legs, eyes, and other organs (illustration, p. 50).

2. How Are Living Things Grouped and Named?

If you could examine a copy of the English dictionary which Nathan Bailey wrote about two hundred years ago, you would find in it some strange definitions. You would find *horse* defined as "a beast well known," and *dog* as "an animal well known." To most people *beast* and *animal* have the same meaning. Hence either of these definitions would fit *horse* or *dog* equally well, or rather, equally poorly, because there is nothing in them to

[1]*Monocystis* (mŏn ō sĭs′ tĭs).
[2]*Cilia* (sĭl′ĭ *ȧ*).
[3]*Bodo* (bō′dō).
[4]*Flagella* (flȧ jĕl′*ȧ*).
[5]*Stylonychia* (stī lō nĭk′ĭ *ȧ*).
[6]*Stentor* (stĕn′tôr).
[7]Page 555.

Above, animals that can glide and soar, but that cannot fly; below, animals that are able to maintain sustained flight · How does man's ability to fly differ from that of the other animals that can fly?

indicate that a horse is in any way different from a dog. Furthermore, either of these definitions would serve for *cat*, *cow*, or any other "animal well known" or "beast well known," just as satisfactorily as for *horse* or *dog*.

Bailey's definition of *cat* is "a domesticated animal that catches and eats mice." This is better than his definitions of *horse* and *dog* because it tells us somewhat more about the animal. But it is not complete enough to be a satisfactory definition (illustration, p. 50).

Such definitions as those just stated would not be found in any modern dictionary. A modern definition of any living thing gives the unique[1] characteristics of that particular plant or animal in considerable detail. Thus, in a modern dictionary, the definition of *horse*, *dog*, or *cat* includes enough of the unique characteristics of the horse, the dog, or the cat so that the entire definition could apply to no other living thing.

THE NEED FOR SCIENTIFIC NAMES · The characteristics given in such definitions have been discovered during many centuries by biologists all over the world. If you examine a dictionary definition of *cat*, *dog*, or other organism, you will find further evidence of the work of biologists. You will find some Latin words. These words are part of the scientific language of biologists.

In order to be able to learn about one another's discoveries concerning living things and to make use of them, the biologists of different countries formerly wrote detailed descriptions of plants and animals in Latin. You may wonder why they wrote them in that language. The reason is that for many centuries Latin served as a universal language among educated people everywhere. Biologists of all nations understood that, for example, the plant described as *Rosa sylvestris vulgaris, flore odorato incarnato* was "the common rose of the forest, having fragrant blossoms of the color of flesh."

Such Latin descriptions might still be in general use by biologists if they had not needed to classify the plants and animals, that is, to put them into groups. But they did need to classify them in order to study them easily and to organize what was known about them. In attempts at such classification, it was not convenient to use even as short a Latin description as the one of the rose plant just given, and this description is so brief that it really tells very little about that plant. A description, to be complete, had to be long. The longer a description was, the less convenient it became to use in any system of classification. Furthermore, every new Latin description that was added to the system of classification made the system more clumsy and difficult to use than before.

Something, therefore, needed to be invented for use in place of the long Latin descriptions in classifying plants and animals. Every organism needed a name which would serve these purposes: (1) The name must be short enough to be conveniently used. (2) It must indicate what kind of animal or plant a particular specimen is. (3) It must fit that particular kind of plant or animal and not any other kind. (4) It must be understood by any biologist in the world, no matter what language he may speak.

THE LINNAEAN SYSTEM · A method of naming plants, which serves all these purposes, is now believed to have been invented, about three hundred and fifty years ago, by a noted French botanist, Bohin.[2] More than

[1] *Unique* (ū nēk′): having no like; alone of its kind.

[2] *Bohin* (bō ă′). Lived, 1560–1624.

Tager, from Gallowa

Can you explain how this picture illustrates the seventh point on page 47?

Ansco

You may laugh at Bailey's definition of *dog* as "an animal well known," but how much better can you do? Can you write a definition of *dog* that will fit a dog and no other animal?

a century later, a Swedish botanist, Linnaeus,[1] put this method into use and brought it prominently to the attention of other botanists. They likewise adopted it. This method was soon found by zoologists to be equally useful in naming animals. It came into wider and wider use in naming plants and animals, until now it is employed by biologists universally.

Hence, in a modern dictionary definition of *horse* you will find *Equus caballus*. The modern definition of *dog* includes *Canis familiaris*, and that of *cat*, *Felis domestica*. *Equus caballus*, *Canis familiaris*, and *Felis domestica* are Latin words and are the scientific names, respectively (in that order), of the horse, the dog, and the cat. These Latin names have been constructed by biologists in accordance with the system, which is called the binomial (two-name) or Linnaean system, after Linnaeus, who brought about its general use. This plan of naming plants and animals is now universally used by scientists (illustration, on this page).

HOW LIVING THINGS ARE CLASSIFIED · [E]The Linnaean system of classifying living things is based on putting together into groups the plants and animals that are closely alike in their structures, or parts. It is assumed that any two or more living things are related if they have homologous[2] structures, that is, structures that are similar and are located in corresponding parts of their bodies (illustrations, pp. 52 and 53). It is further assumed that the more nearly alike their structures are, the more closely related the organisms must be. Thus cats, lions, tigers, and leopards are put into the same group because the shapes and positions of their legs, tails, eyes, and other structures are so much alike (illustration, p. 54).

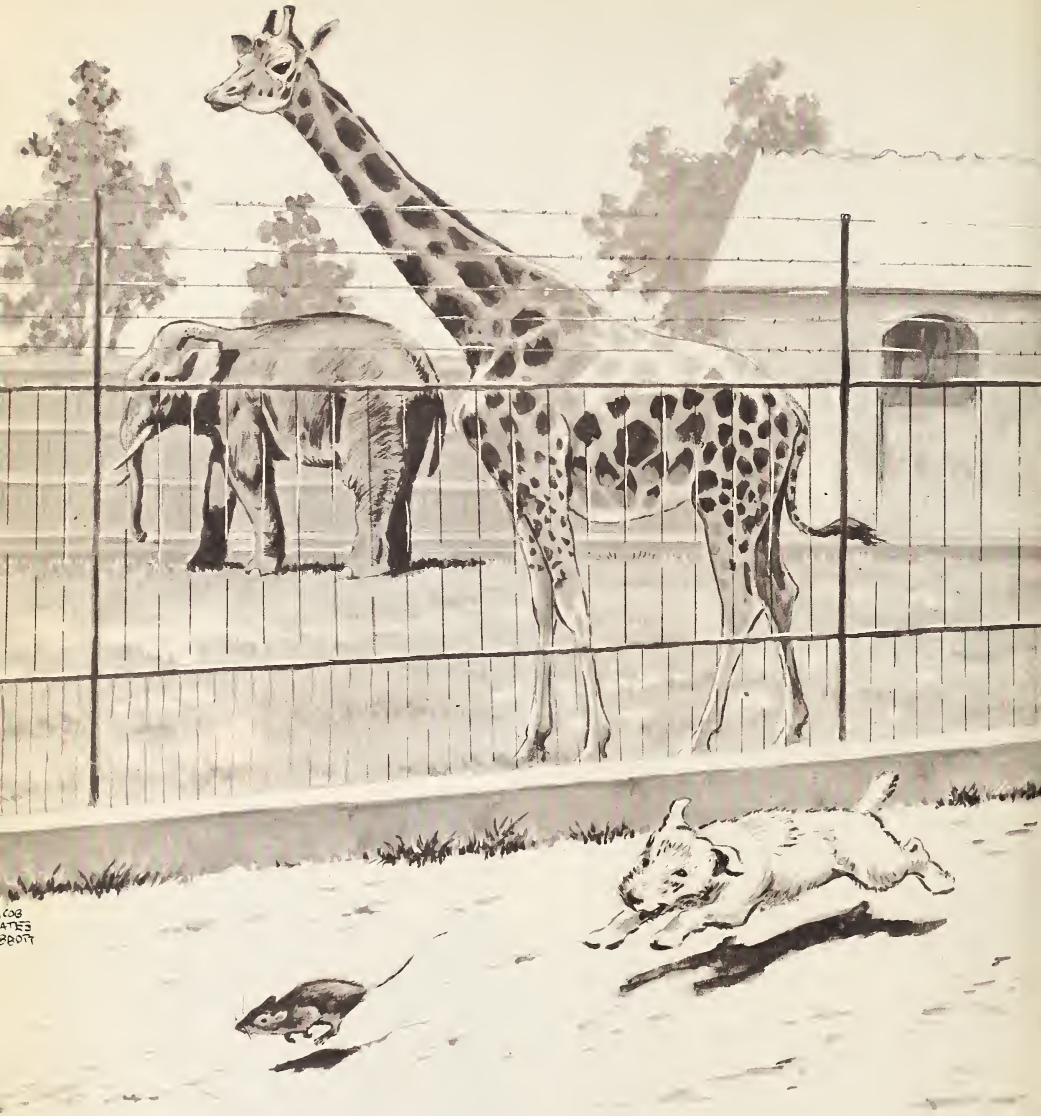
It is easy to see that these cat-like animals are enough alike in structures to be put into a group together. It is not so easy to see that elephants, insects, and snakes are enough alike to be put together into any sort of group. But elephants, insects, and snakes are all animals. Hence they can all be put

This animal (*Baluchitherium*) lived ages ago. Scientists believe that it is the largest land mammal[3] that ever lived. They have found out from a study of its bones not only how it looked, but also what it ate and many other facts about it. Scientists have been able to classify it positively and hundreds of other animals long since extinct. To what animal now living does this animal look to you to be most closely related?

[3]Page 40.

American Museum of Natural History

[1]*Linnaeus* (lĭ nē′ŭs). Lived, 1707–1778.
[2]*Homologous* (hō mŏl′ō gŭs).



The neck of each of these mammals[1] has only seven bones.
What do scientists conclude from this fact?

[1]Footnote 1, p. 5.

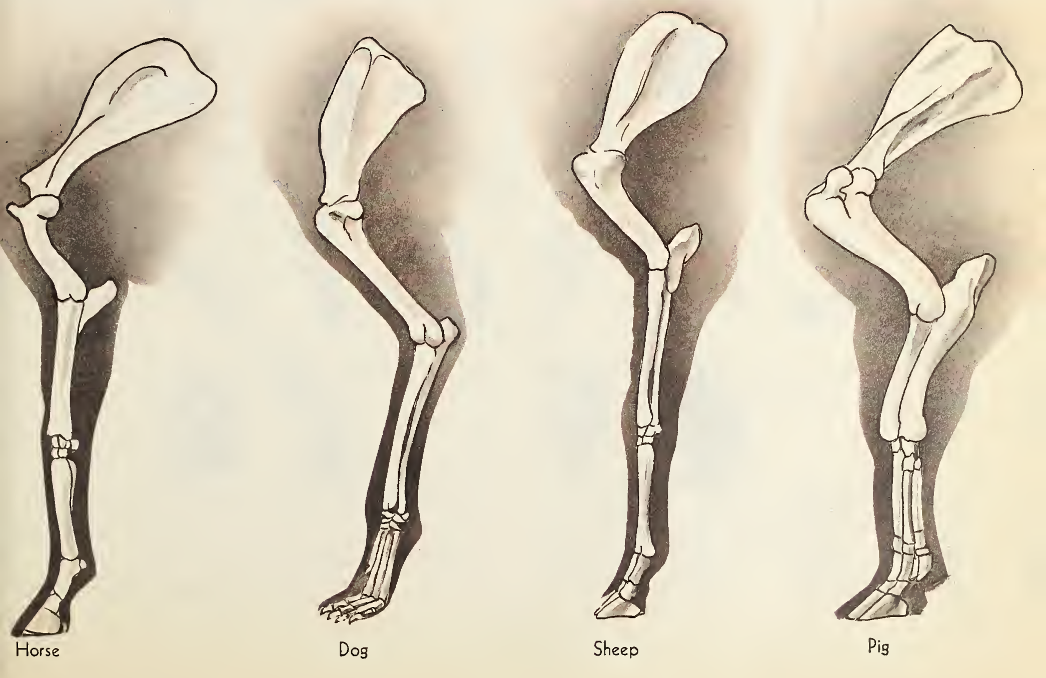
into the great group that includes all the animals. In fact, every animal has enough characteristics in common with every other animal so that both can be placed together in some group in the system of classification. The same is true of plants.

The scheme of classification consists of seven principal divisions (illustration, p. 54). It begins with the division *kingdom*, in which the living things are least alike, and usually ends with the division *species*, in which they are very closely alike. The classifications of six common organisms follows on page 55.

[E]The scientific name of any animal or plant is made up of the names of the genus and species to which it belongs. Thus the scientific name for "cat" consists of the genus name, *Felis* ("cat"), and the species name, *domestica* ("domestic"). That for "dog" consists of the genus name, *Canis* ("dog"), and the species name, *familiaris* ("familiar," or "common"). Any cat is *Felis domestica* ("domestic cat"), and any dog is *Canis familiaris* ("common dog"). The scientific name for "man" is *Homo* ("man") *sapiens* ("wise").

In the complete system of classification the species is further divided into varieties. Thus the species *Felis domestica* is made up of the varieties Manx, Persian, Angora, Maltese, and others. The species *Canis familiaris* is composed of varieties, such as setter, bulldog, terrier, and shepherd. Varieties are further classified into breeds. For example, the variety *setter* includes Llewellin, Gordon, English, Irish, and other breeds of setter dogs.

The fore-limbs of four animals · What evidence do you see here that these animals are related?



How cat and dog are classified · Can you check here all the divisions stated on page 55? Of the six organisms whose classifications are given on page 55, which belong to the same kingdoms? phyla? classes? orders? families?

Cat

N.B.

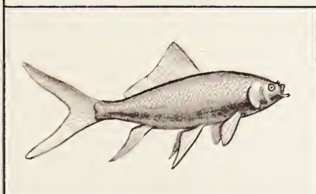
KINGDOM—Animal
PHYLUM—Chordata
CLASS—Mammalia
ORDER—Carnivora
Family—Felidae
Genus—Felis
species—domestica

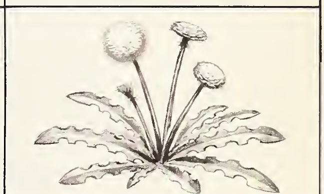
Dog

KINGDOM—Animal
PHYLUM—Chordata
CLASS—Mammalia
ORDER—Carnivora
Family—Canidae
Genus—Canis
species—familiaris

Horse

KINGDOM—Animal
PHYLUM—Chordata
CLASS—Mammalia
ORDER—Ungulata
Family—Equidae
Genus—Equus
species—caballus





Goldfish

KINGDOM—Animal
PHYLUM—Chordata
CLASS—Pisces
ORDER—Teleostei
Family—Cyprinidae
Genus—Carassius
species—auratus

House-fly

KINGDOM—Animal
PHYLUM—Arthropoda
CLASS—Insecta
ORDER—Diptera
Family—Muscidae
Genus—Musca
species—domestica

Dandelion

KINGDOM—Plant
PHYLUM—Spermatophyta
CLASS—Dicotyledones
ORDER—Campanulales
Family—Compositae
Genus—Taraxacum
species—officinale

A UNIVERSAL LANGUAGE · Not all the kinds of plants and animals have yet been discovered and named. But hundreds of thousands have been. Each has been put into its proper place in the scheme of classification and has been given a Latin name, similar to *Felis domestica* and *Canis familiaris*, indicating its genus and species. These Latin names serve as a universal language. They are used by biologists all over the world.

A UNIVERSAL SYSTEM · Various parts of the system of classification are published in books called "keys." Thus there are "bird keys," "flower keys," "fish keys," "mush-

room keys," and many others. They are printed in English, Chinese, Spanish, or any other language, but the genus, species, and other group names are always in Latin.

With these keys any biologist can find out the phylum, class, order, family, genus, and species of any known kind of animal or plant (illustration on this page). After the name of each group (phylum, class, etc.) in the key is a description of it, that is, a statement of the chief characteristics that all the plants or animals that belong to that group have. For example, the description of Chordata, the phylum to which the dog, the cat, and the horse belong, begins with "Animals having, at some stage of their development, a notochord."[1] A species name, such as *familiaris* or *domestica*, is followed by a description of the unique characteristics of the particular kind of animal or plant indicated.

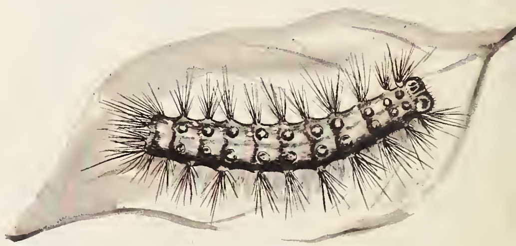
After a scientist has found out the detailed characteristics of a specimen, he can trace those characteristics, step by step, down through phylum, class, order, etc. to the species. Then by putting together the genus and species names he can arrive at the scientific name. If he hears or reads an unfamiliar scientific name, he can readily find the name in the proper key. He can then easily trace the family, order, class, and phylum to which that kind of plant or animal belongs.

[1]Page 539.

Not even a trained biologist can always tell how closely related various living things are, merely from their looks. All four of these animals look like worms, but only the sandworm is a worm. *A* and *B* belong to the same order. *A*, *B*, and *C* belong to the same phylum. *D* belongs to a different phylum from that to which the other three belong, but to the same kingdom.

Which two are most closely related? Explain

A. Cabbage-butterfly larva



B. Gypsy-moth larva

C. Centipede

D. Sandworm

USING THE LINNAEAN SYSTEM OF CLASSIFICATION · The following incident shows how the Linnaean system of classification was actually used:

About ten years ago the American scientist William Beebe[1] began exploring the ocean off the coast of Bermuda, in his "bathysphere," a great hollow, steel ball. Inside it Beebe and an assistant could be lowered into the ocean to depths considerably greater than those to which divers in ordinary diving suits are able to descend. Seated comfortably in this ball, with the light of a powerful searchlight directed through the quartz window, the men could observe the submerged reefs and land formations, as well as the marine plant and animal life (illustration, p. 58).

After one of his exploring trips in the bathysphere, Beebe announced that he had discovered a "new" fish. By a "new" fish he meant one that had never been reported before by any scientist. Later, when biologists read his detailed description of this fish, they confirmed his statement that it had not previously been known to science.

Beebe had proceeded in this way: By careful observations of the fish, as it swam about outside the window of the bathysphere, and probably also by studying photographs of it, he discovered and recorded as many of its unique characteristics as he could. Then he was ready to identify it in his key. He did not need to determine the kingdom, phylum, or class, because he knew that all fishes belong to the same class. By comparing the characteristics of his specimen with the descriptions of the smaller groups in his key, he was able to determine first the order, then the family, and then the genus to which it belonged. Among the different species described under that genus, however, Beebe could find none that had certain of the characteristics that his specimen had. Hence he knew that the fish he had discovered belonged to a new species.

Either Beebe or some other scientist or scientists would later give that particular kind of fish a Latin species name. That name would then be added, along with Beebe's description of the unique characteristics of the fish, under the proper genus name in the universal "fish key."

Most people make little or no use of the scientific names of plants and animals. You may never need to use them. But knowing how living things are named and classified will help you to understand biology.[2]

Checking What You Know

BIOLOGICAL FACTS · The following test items are of the Modified True-False type. This type and others used in this book are described and explained in "This Book and You," p. xiv.

Pages 39–47. **1.** The entire body of a protozoan is composed of *many cells*.

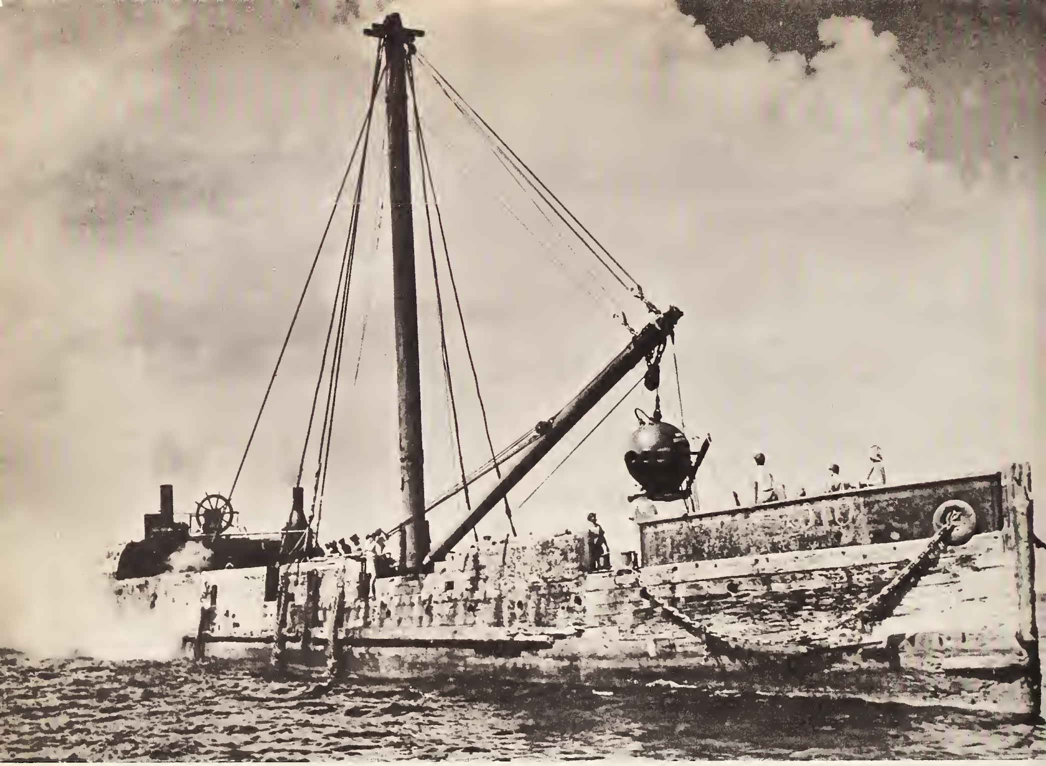
2. The cells that make up an elephant's body are in general *no larger* in size than those that compose a mouse's body.

3. Protoplasm is *one kind* of living material.

4. Protoplasm is composed chiefly of *carbon*, *hydrogen*, ~~*helium*~~, *nitrogen*, and *sulfur*.

[1]*Beebe* (bē'bē). Born, 1877; still living.

[2]To the Teacher. Teachers wishing to include further study of classification in the course will probably want to continue at this point with the materials beginning on page 511. Teachers who do not wish to emphasize classification to this extent may omit those materials for class study, but will find them useful and convenient for pupil reference. Frequent footnotes throughout the text connect and integrate the materials of the various areas with those of classification.



Keyst

Lowering the bathysphere into the ocean · Beebe's assistant took still and motion-picture photographs through the windows of the bathysphere. Also, he wrote, in short-hand, descriptions of what was observed. Which of the ways in which scientists work (p. 570) are illustrated by these procedures?

5. The *cytoplasm* of a cell is composed of thicker, less watery protoplasm than the rest of the contents of a cell.

6. Most cells that readily change their shapes when the tissue containing them is pressed have cell *walls*.

7. The lining of your mouth is *a tissue*.

8. Your nose is an example of *a tissue*.

9. The heart and all the tubes through which the blood flows make up *a tissue*.

10. The eye is an example of *a system*.

11. Whenever you drive a nail, your hands and your eyes do different things, which help in doing the work. Such working together is an example of *biological succession*.

Pages 47–57. 12. *Bailey* originated the modern method of classifying living things.

13. Living things are said to be closely related if they have many *homologous* structures.

14. Cats and dogs are more closely related than cats and horses because cats and dogs belong to the same *kingdom*, *phylum*, *class*, and *species*, but cats and horses do not.

15. A *species* may be subdivided into orders.

16. A *family* is a larger division in classification than a *genus* or a *class*.

17. The scientific name of the robin is "Turdus migratorius." These two Latin words tell the *order* and the *species* to which the robin belongs.

BIOLOGICAL PRINCIPLES · (See "This Book and You," p. xii.) Here is a list of biological principles which are stated, explained, or illustrated in the chapter that you have just studied. It is important for you to be able to explain and give an example of each of them in your own words and, if possible, from your own knowledge and experience.

1. Living things vary in size from those too small to be seen, even with a microscope, to those as large as whales and big trees.

2. All living things are made up of one or more cells.

3. Cells are about the same size in both large and small living things, but large organisms are composed of enormously greater numbers of cells than are small organisms.

4. All living things are composed of protoplasm, which differs in different kinds of living things and in different parts of the same organism.

5. Cells are organized into tissues, tissues into organs, and organs into organ-systems.

6. In all but the simplest living things there is a division of labor, in which the work of the organism is divided among special tissues, organs, and organ-systems.

7. Those kinds of living things are most likely to continue to exist which are best adapted to their habitats.

BIOLOGICAL TERMS

**algae	**nucleus
**aquatic	**organ
**cell	**organ-system
**division of labor	**protoplasm
**function	**Protozoa
**locomotion	**tissue

Applying and Extending What You Know

AS SCIENTISTS WORK AND THINK · 1. Which scientific attitudes (p. 571) influenced Beebe to descend into the ocean in his bathysphere? Which of the attitudes are indicated by his explorations in the bathysphere? by his procedures in classifying the new kind of fish that he discovered?

2. Robert Hooke,[1] an English scientist, is credited with having obtained the first knowledge of cells. While examining a thin slice of cork under a magnifying glass (lens), he saw that it was made up of little spaces surrounded by walls. These walled spaces reminded him of the cells, or rooms, in which monks live in a monastery. Hence he called them cells.

In many books of biology the statement is made, or the impression is given, that Hooke never discovered, later, that living cells had contents, but that he always believed them to be empty, as he thought the cork cells were. Yet in his book *Micrographia* he says, ". . . in several . . . vegetables, whil'st green, I have, with my microscope, plainly enough discover'd these Cells . . . filled with juices."

Which of the scientific attitudes are related to this error in many biology books?

3. On page 40 you were given directions for obtaining minute plants and animals for study. Did you wonder how these living things came to be in the jars? If you did, you were discovering problems as scientists do. Try to devise (invent) a way of answering the question. Make a list of ways in which you think the living things might have got into the jars. Then plan and, if possible, carry out experiments to test those different ways. For example, the organisms might

[1] *Hooke* (hŏŏk): lived, 1635–1703.

have fallen into the jars from the air. How would you test this possibility? After you have made your plans, check to see how many of the elements of scientific method (p. 570) you have used.

APPLYING YOUR KNOWLEDGE OF BIOLOGY · 1. Why is the gray squirrel a successful kind of animal? Why is the fir tree or the ragweed a successful kind of plant? Can you name other successful living things in your community? Why do you consider them successful? What structures do they have which you think help to make them successful?

2. Dogs, wolves, foxes, and coyotes are all members of the same family of animals. Why are they classified in the same family? Wolves, dogs, and coyotes are classified in one genus, and foxes in three genera. Why is this?

3. In which of the groups of enemies (legend, illustration, p. 46) would each of the following belong: severe wind-storms; fleas on a dog; extremely high or low temperatures; mold plants growing on bread; a board laid over the grass of a lawn?

TOPIC FOR INDIVIDUAL STUDY · 1. In an encyclopedia or some other reference book read the life stories of Leeuwenhoek, Schleiden, Schwann, and Hooke, who made important early discoveries of simple forms of life or of cell structures. Take notes of important incidents as materials for reports in the classroom or the science club, or for English themes.

2. Is the horse more or less closely related to the dog than is the cat (illustration, p. 55)? Explain. Using a "big" dictionary, a college zoology textbook, and encyclopedias, can you find several different animals that belong to the horse family, Equidae, the genus, *Equus*, and the species, *caballus*?

EXPERIMENTS · 1. What are the characteristics of a typical[1] plant cell? Obtain an onion, a glass microscope slide, a cover slip, a microscope, a medicine-dropper, and a little tincture of iodine. Using the medicine-dropper, put a small drop of water on the microscope slide. Then with a knife blade or tweezers peel a very thin bit of tissue from the outside of one of the inner layers of the onion. The thinner the tissue is, the better your results will be. If you are careful, you can secure a piece of tissue that consists of only one layer of cells.

Place the tissue in the drop of water so that it is spread out in a single layer. Now add a very small drop of tincture of iodine. Carefully place the cover slip on the drop containing the tissue. This process of making a microscope slide is called "making a mount" or "mounting."

Examine the mount with, first, the low power and later the high power of the microscope. What parts of the cells do you see? What are the shapes of the cells? Do they vary greatly in size and shape? Make and label one or more sketches of a piece of the tissue and of one or more separate cells to show what you have observed.

2. What are the characteristics of a typical animal cell? Put a frog into a jar in which there is about an inch of water. Cover the jar so that the frog cannot escape, and leave the animal there over-night. Do not worry for fear that the animal will not have enough air, for it will. Remove the frog the next day. In the water you will find white, thin flakes of tissue. These are bits of the outer skin of the frog.

Mount a small piece of this skin tissue in a drop of water on a microscope slide. Make sure that the skin is flat and not rolled or doubled up. Add a small drop of fountain-pen ink to the mount. The ink will make the various parts of the cell more clearly visible. Complete the mount by carefully putting the cover slip over the water, ink, and skin.

Use first the low power and later the high power of the microscope to examine the cells. Do they vary greatly in size and shape? Do they have thick walls or thin membranes? Note the nuclei. Is the nucleus generally located in the same part of each cell? How can you dis-

[1] *Typical* (tĭp'ĭ kăl): showing the essential characteristics which all members of a certain group possess. *Typical* and *unique* have opposite meanings.

tinguish the nuclei from other cell structures? Make and label sketches to indicate the facts that you consider important about these cells.

PROJECT · *To construct a model of a typical cell, using modeling clay, cellophane, paste, and fine wire.* Put in the nucleus and other structures which you think should be there. Remember that cells have three dimensions, and are not flat, as they appear under the microscope to be.

BULLETIN-BOARD DISPLAYS · **1.** Make, on the bulletin board of your biology classroom, a display of pictures of animals belonging to the same family—for example, the cat family, the dog family, or the horse family. Find out the scientific name of each animal by consulting a college zoology textbook or a "big" dictionary. Write the name under each picture. Write under the group as complete a list of homologous structures as you can (pp. 51, 52, and 53).

2. Although we commonly speak of "an oak tree" or "a maple tree," the terms *oak* and *maple* are really equivalent to genus names. Each kind of oak or maple tree is a species of the genus *oak* or *maple*. Make a collection of leaves from different kinds of oak or maple trees, and paste them on sheets of heavy paper. Under each write both its common name and its scientific name, which you can find in a "big" dictionary or in a college textbook of botany. Display them on the bulletin board.

BOOKS FOR REFERENCE

YATES, R. F. *Fun with Your Microscope.* D. Appleton-Century Company, Inc.

BOOKS FOR LEISURE READING

BEEBE, WILLIAM. *Half Mile Down.* Harcourt, Brace and Company.

DORRANCE, ANNE. *Green Cargoes.* Doubleday & Company, Inc.

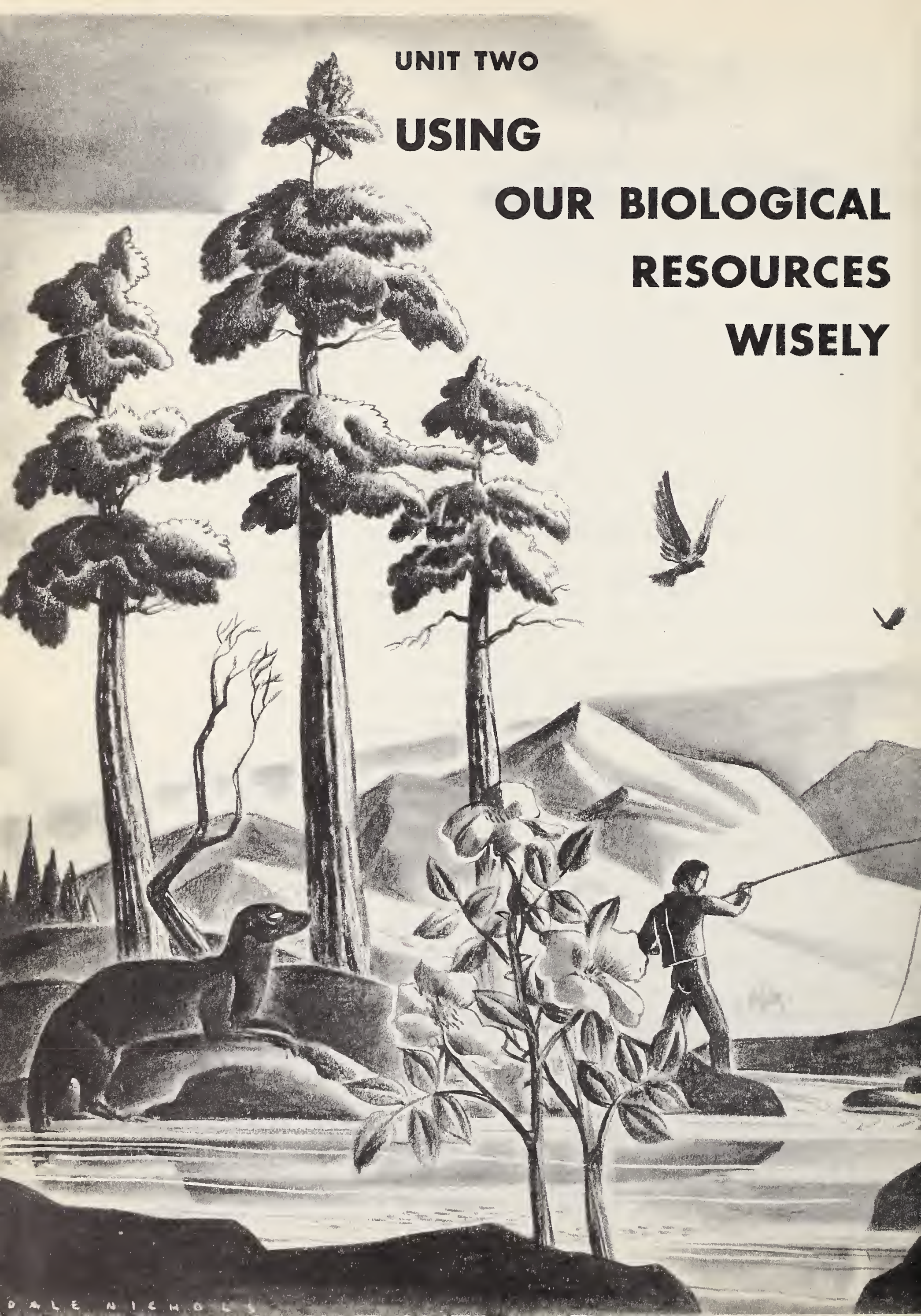
PEATTIE, D. C. *This Is Living.* Dodd, Mead & Company.

To which of the animals shown in the illustrations on pages 55 and 549 do you think the cow is most closely related? Justify your answer

Soil Conservation Service

UNIT TWO

USING OUR BIOLOGICAL RESOURCES WISELY



What are some important biological problems that are related to soil conservation?

What are some important biological problems that are related to the conservation of forests and wild life?

3

CONSERVATION OF THE SOIL

1. How Did the Earth Become Covered with Soil?

Scientists believe that "when the world was young," it was nothing but a mass of rock. It had no atmosphere, no water, and no soil. Also, there was then no life of any sort on it. There was no part of the earth at that time where any kind of plant or animal would have been able to live.

Century after century the nature of the earth's surface remained unchanged. It was much like that of the moon today, with its bleak expanses of never-changing rock.

If you are interested in learning more about what scientists believe, in general, the early history of the earth to have been, you can find out from a textbook of geology or astronomy. The story of biological conservation,**[1] however, begins with a study of the soil.

CHANGING ROCKS TO SOIL · The first soil was formed on the earth's surface after an atmosphere had been formed around the solid earth. DEF The process by which rocks are changed to soil is called weathering.*[2] Weathering is usually considered to include both (1) the cracking and breaking of rocks, as by sudden changes of temperature and by the freezing of water; and (2) the changing of their exposed surfaces by the chemical action of oxygen, water, carbon dioxide, and, to a lesser extent, some other substances in the air. Weathering caused the ancient rocks to crumble, or "decay." The loose materials that resulted from these chemical and physical changes were the first soil (illustration, p. 65).

DEF A *chemical change* is one in which a substance is changed into one or more substances that are different in composition from the original one. Thus a chemical change takes place when wood decays or when milk sours. DEF A *physical change* is one in which a substance is changed in form, size, or state, but still has the same chemical composition that it had before the change. For example, a physical change takes place when ice melts and thus water changes from a solid state to a liquid state, or when you cut an apple into pieces. The changing, by the air, of the composition of rock so that it becomes soil is a chemical change. The crumbling of the changed rock into smaller pieces is a physical change.

The changing of rocks to soil by weathering is going on today in the same way as in past ages.

The solid part of the earth was always composed of most, if not all, of the same elements**[3] that compose it now. DEF An element is a substance that cannot be broken up into two or more simpler substances or changed into any simpler substance.[4] Thus oxygen, gold, aluminum, and carbon are elements.

[1]*Conservation* (kŏn sẽr vā′shŭn).
[2]*Weathering* (wĕth′ẽr ĭng).

[3]*Element* (ĕl′ē mĕnt).
[4]This statement is true for all practical purposes. In atomic research involving atom-smashing, however, elements are made to change.

There are in all ninety-two natural elements, and the earth, the sun, plants, animals, and everything else are made up of one or more of these elements.[1]

[E]Elements combine with other elements to form substances called compounds** (illustration, p. 66). For example, the elements hydrogen and oxygen combine to form the compound water (hydrogen oxide). Compounds can act upon one another to form other compounds. A compound is always different from each of the elements or compounds that combined to form it.

[1]These ninety-two elements are those that are found in nature. There are, in addition, the man-made elements created by scientists in the progress of atomic research, which include plutonium, neptunium, americium, and curium.

[E]Elements and compounds often remain together without combining, as in a bowl of flour, salt, and sugar. Together they are then a mixture.** Thus the air is neither an element nor a compound, but instead is a mixture of many elements and compounds. The elements in the air include oxygen and nitrogen, and the compounds include water, carbon dioxide, and ammonia.

The original rocks of the earth were composed both of elements, such as iron and nickel, in a pure state, and of compounds of these and many other elements, including calcium, silicon, aluminum, sulfur, and iodine. After an atmosphere had been formed around the solid earth, these substances combined with the oxygen, water, and carbon dioxide in the air to form still other com-

What evidences of physical and chemical changes do you see here?

Gifford, from Oregon State Highway Department

The sand grains are compounds made up of the two elements silicon and oxygen. The sea water is a mixture chiefly of the compounds water and salt. What elements chiefly make up the protoplasm of the horses and riders?[1]

pounds. Mixtures of these compounds in the form chiefly of rock particles made up the soil. These solid compounds, which are neither plant nor animal matter, and hence are inorganic matter, are called minerals.[2]

E The first soil was not like our farm and garden soil today. It was composed entirely of minerals. It did not contain any humus,**[3] that is, decaying organic matter. It could not contain humus, because at the time that the first rocks were weathered into soil there were not yet any plants or animals on the earth.

DEF

THE SHIFTING OF THE SOIL · Until there was an atmosphere, there could be no running water, no winds, and no glaciers. Water flows, wind blows, and glaciers move down mountain-sides for the same reason that rain falls upon the earth, namely, because they are pulled by the force of gravity toward the center of the earth. Running water, winds, and glaciers are the chief agents that

[1]Page 41.

[2]Some confusion results from the practice of using different meanings for *mineral* in books and articles dealing with nutrition and other aspects of biology. In this book *mineral* is used to mean an inorganic compound which serves plants and animals as a source of elements out of which their various structures are made. Chemists and geologists use a different definition from any used in biology.

[3]*Humus* (hū'mŭs).

shift soil on the earth. The process by which portions of the rock and soil are scoured or scraped off and carried away by running water, winds, glaciers, and other agents is known as erosion*[1] (illustration below).

By water. It is believed that there was water vapor in the air for a long period before there was any rainfall. Finally, however, the water vapor condensed and fell as rain. It ran off the higher surfaces to the lowest depressions, where, in time, it formed oceans. As it flowed, it changed the earth's surface greatly. It removed particles of soil and carried them along with it, just as running water does today. Also, it dissolved some of the minerals out of the rocks over which it ran and carried them off.

Where the surfaces were steep, the water flowed rapidly, for there was nothing to slow its progress. The rock particles in the water served as "cutting tools," which dug into the rock surfaces. Thus, in the course of time, the running water made furrows and chan-

[1]*Erosion* (ē̇ rō′zhŭn).

Do you think that weathering or erosion is probably causing the greatest changes here? Which of the agents of erosion do you think is probably most active here? Explain. What evidences of weathering and erosion do you see in the illustration on page 66?

National Parks Bureau, Canada

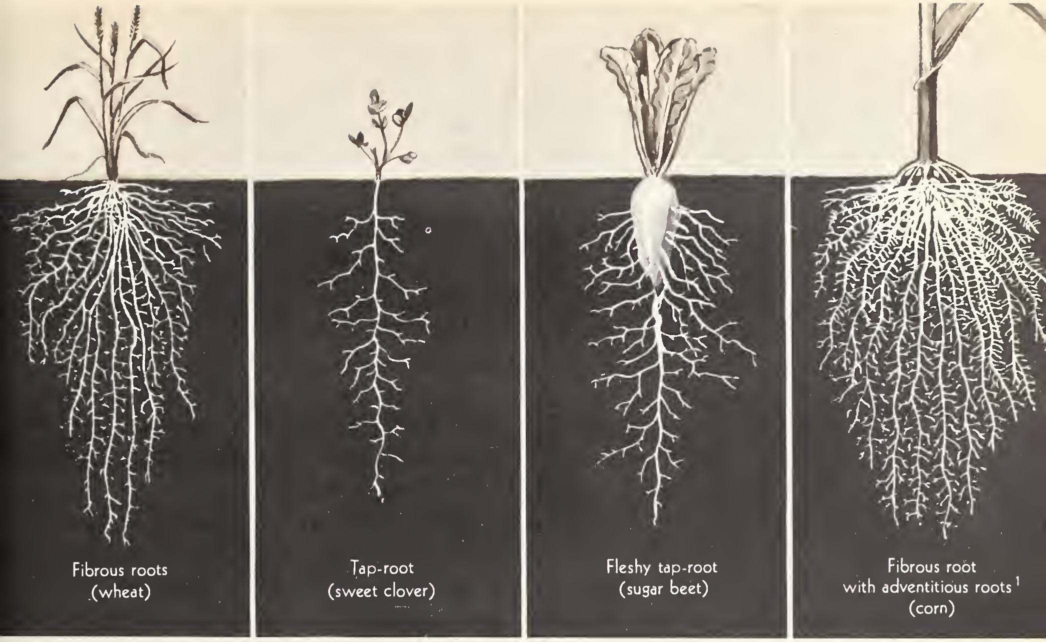
nels in the rock. Much of the loose soil that the water was carrying along, together with the minerals it dissolved and the particles of rock it "gnawed" out in its progress, was shifted, by stages, into the oceans.

Wherever the soil was eroded away so that the rock surfaces became exposed, the air acted upon the rock, weathering it into soil. Also, the rock may have become broken where it was heated by the sun or the earth's heat and then quickly cooled, or was cooled and then quickly heated. It became broken, too, where water got into cracks and then froze, because water expands with great force when it freezes. The broken rock presented more surface to the air and was therefore more readily changed to soil. Thus soil-making (weathering) and soil-shifting (erosion) were going on all over the earth at the same time.

By winds. As soon as there was an atmosphere, there were winds. These winds picked up dust and transported it to other locations. The smallest particles were, of course, carried farthest. As the winds blew dust against rock surfaces, they scoured off particles of the surfaces and carried them away, along with the dust that they already carried, as winds do today. The shifting of

The Bad Lands of South Dakota are the result of extensive erosion. How do you account for the fact that trees can grow in the gorge?

United States Geological Survey



The type of root system that a plant has greatly affects the amount of erosion of soil about the plant. Which of these types of plant roots do you think would be of most value, and which of least value, in preventing erosion? Explain. Can you suggest at least two other factors besides root systems that affect the rate of erosion in a field?

soil by winds changed the earth's surface. It piled up hills or ridges of sand (dunes) in some places, and made deposits of the finer particles in the oceans.

By glaciers. Until there were rain and snow, there could be no glaciers. Glaciers are great masses of ice that slowly slide down the sides and valleys of mountains (illustration, p. 67). They may move only a few feet each year, but, because of their tremendous weight, they are mighty agents of erosion. As they go, they plow out and scour out the rocks and soil over which they pass, and carry with them, down into the valleys, the material thus eroded. There the ice melts, leaving the load of soil and pieces of broken rock in deposits where the glacier ends.

The streams which the melting ice forms take up the work of erosion where the glaciers leave off. They pick up and carry the deposits of soil and rock by degrees to the ocean. Also, as the areas become dry, the prevailing winds carry off huge quantities of soil as dust.

Practically all of Canada, as well as parts of the northern United States, including considerable areas of New England, Pennsylvania, New York, New Jersey, and the Middle West, are covered with soil and gravel

[1]*Adventitious* (ăd vĕn tĭsh′ ŭs) root: a root out of the usual place. The adventitious roots of corn serve as prop, or brace, roots.

that were deposited by glaciers. These glaciers joined to form great sheets of ice that almost completely covered and slowly flowed over these regions long ago. At the present time, however, glaciers are much less important as agents of erosion than are running water and winds.

Plants reduce erosion. Until land plants became established over the earth's surface, there was nothing to stop the shifting of soil by running water and wind. In ways that will be described later, the plants anchored the soil and slowed down erosion. Erosion did not cease, of course. But where the land became covered with vegetation, the rate of erosion was so reduced that the rock was changed to soil more rapidly than the soil was eroded—though soil is formed only at the rate of about an inch in several hundred years (illustration, p. 69).

Plants and soil-making. Before there were any terrestrial plants, the soil was composed entirely of inorganic matter. As soon as land plants became established, however, the nature of the soil was changed by the plants. An example of how plants aid in soil-making is furnished by lichens[1] (illustration, p. 558). Lichens were among the earliest soil-making plants. They covered rocks where practically no other plants could grow. As their root-like structures (rhizoids[2]) grew in the tiny cracks, they gave off substances that produced chemical changes in the rock. Also, they sometimes exerted enough pressure to break off minute particles. Thus they helped to break up the rock and to expose it to the weathering action of the air. Later, when they died, their bodies were added as humus to the soil.

[1]Page 557. [2]*Rhizoid* (rī′zoid).

The results of up-and-down-hill plowing · The top-soil, which has been eroded away and hence lost to the farmer, is part of the richest soil in the field. Explain

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[E]Without humus in the soil, higher plants will not grow. Hence the early lichens and other simple terrestrial plants, especially mosses,[1] made the soil suitable for higher plants.[2] These higher plants, as they became established later, continued the same processes of soil-making as those just described. To the plant humus was added animal humus as the decaying bodies and products of animals were made a part of the soil.

Top-soil, sub-soil, and bed-rock. The soil in most places consists of two layers, the top-soil and, beneath it, the sub-soil (p. 70). Below the sub-soil is bed-rock. The top-soil is a mixture of inorganic matter and organic matter because it contains both weathered soil and humus. The sub-soil consists only of inorganic matter, since it is weathered soil without humus. The bed-rock is the rock that has not been exposed to the air and consequently has not been weathered into soil.

[E]The thickness of the top-soil varies greatly in different localities. On hillsides, especially where the water can run off freely, the top-soil is likely to be thin. In valleys it is likely to be deep because of the erosion of the soil from the hillsides into the valleys by running water. In most regions, however, the layer of top-soil is only a few inches deep. Hence, because our food crops will not grow in any soil except the top-soil, it has been said that only a few inches of soil stand between the world and starvation.

The problem of soil conservation, therefore, is one of learning how our fertile soil is constantly being lost and how to save what remains.

2. How Is the Top-soil Eroded Away?

In parts of Canada and the United States where the great ice sheet deposited its enormous loads of gravelly soil, there is much stony farm land. With heavy toil the farmers had to remove most of the larger stones from the top of the ground in their fields before they could raise crops. But the fields did not stay free from stones long. In a few years the farmers found that there were about as many stones in sight on their farm land as there had been at first. Furthermore, in some spots the tops of great rocks which had not been visible before now stuck up through the soil.

Here was a mystery. Where did all the stones come from? Some of the farmers concluded that stones grew. They thought that the large stones which they found on their fields must have grown from those that had been too small to remove when the fields had been cleared of stones earlier.

NOT BIGGER STONES BUT LESS SOIL · Later the mystery was solved when the farmers found not only more stones, but also patches of sub-soil appearing in their fields. Then they knew that the increasing numbers of stones that were appearing on the surface of their fields had been in the ground all the time, and that they were being uncovered year by year, as the top-soil was being washed away.

REASONS FOR RAPID EROSION · The rapid erosion of farm land by water, such as that which those farmers observed on their farms, has been going on not only in the regions which were covered by the Great Ice Sheet,

[1]Page 559. [2]Pages 562–564.

but all over the United States and Canada ever since the early colonists established farms. There are several reasons for such losses of fertile soil. Among the most important are these:

1. **Methods of using the land.** The early colonists on this continent came from northwestern Europe. There the rains are for the most part gentle. The crops best suited to this type of rainfall are closely planted grains, such as barley, rye, and wheat. The gentle rains produce relatively little erosion on the well-covered fields.

The colonists naturally introduced in their new homes the same farming practices that they had used in their native lands. In the United States and Canada, however, violent rain-storms are common in many agricultural areas. Sometimes several inches of rain falls during a few hours. Such storms produce far greater erosion with grain crops than gentle rains do. Furthermore, as farming developed in these two countries, corn, tobacco, and cotton became important crops in certain sections. The seeds of such crops are not closely planted, as are those of the small grains. In order to grow well, these plants need to be relatively far apart. Also, they need to have the soil between them cultivated frequently. Hence the growing of these crops exposed the bare ground to the heavy rains. Rapid erosion resulted.

Falling rain greatly reduces soil fertility by two other processes besides the erosion which it indirectly causes. Erosion carries minerals away along with the soil. These other processes (leaching and elutriation[1]) result in dissolving the minerals of the soil and carrying them away as part of the soil water. Leaching and elutriation will be described more completely later.

[1] *Elutriation* (ē lū trĭ ā′shŭn).

contour

2. **Methods of plowing.** Most of the plowing has always been carried on with "moldboard" plows (illustration, p. 81). These plows turn over the sod. Thus they put the grass or stubble underneath and expose the soil. Also, until recently it has been the almost universal practice to plow in straight lines, up and down the slopes. As a result, the plow furrows in the bare soil served as channels down which the rain water raced, carrying the soil with it (illustration, p. 70).

3. **Methods of grazing.** In the grazing country the stock-men wanted to raise as many cattle and sheep as possible. Hence in many localities they put more animals on the land than the grass could support. Consequently the animals killed the grass by eating it down to the roots. When the grass died, the land, without its covering of vegetation, was rapidly eroded, both by water and by wind.

4. **Destruction of forests.** As will be explained later, the destruction of vast forest areas resulted in the rapid run-off of rainfall and consequently in floods. Floods sweeping over farm and grazing land have caused extensive and serious erosion.

EROSION BY RUNNING WATER · **Sheet erosion.** Running water causes two types of erosion, namely, sheet erosion and gully erosion. Sheet erosion is much the more serious, but it is much less likely to be noticed. Sheet erosion is the removal of the top-soil in thin layers from areas varying from small plots to great regions (illustration *A*, p. 73).

No land is ever perfectly level, and water always flows from higher to lower ground. As it flows, it takes loose soil along with it. Of course the steeper the slope and the barer the soil, the swifter is the flow and the greater the amount of sheet erosion. Sheet erosion is often so gradual, however, that farmers do not realize that it is taking place.

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What evidence of sheet erosion is shown above? Nearly eight hundred million acres in the United States have lost from one fourth to three fourths of their top-soil. Gully erosion (below) has already partly destroyed or ruined areas in the United States equal to those of Texas and California combined. Can you explain why a sloping field often has sheet erosion at the top and gully erosion at the bottom?

As a result, many farms have been ruined before measures to protect the top-soil have been taken.

Gully erosion. Gully erosion occurs when the water runs off the land rapidly enough to dig gullies, or ditches, in the soil. It usually occurs after sheet erosion has removed most of the top-soil. Sub-soil that is not held together by humus is readily gullied.

Illustration *B*, p. 73, shows a gully in Stewart County, Georgia. It was begun about fifty years ago by the drip from a barn. It is now more than a hundred feet deep. Where this gully now is there were once hundreds of acres of good farm land, a house, a school, and the barn that started the trouble. Long before the drip from the barn started the gully, however, the top-soil of the adjoining fields had already suffered considerable damage from sheet erosion. The erosion here is still going on and will continue to spread unless checked.

SHEET EROSION BY WIND · Did you ever see it rain mud instead of water? If you had been in certain parts of the Middle West soon after the great dust storm of May, 1934, you would have seen cars, houses, and everything else covered with mud during showers. This dust storm, or "black blizzard," began in the southern Middle West and swept eastward. In a few days the wind, with its load of precious top-soil, reached the Atlantic coast. Dust settled even upon vessels several hundred miles from shore in the Atlantic Ocean. The United States Soil Conservation Service estimated that three hundred million tons of rich top-soil was removed from farms by that one dust storm.

This dust storm was the most terrible and destructive of all that have occurred in the United States (illustration below). Yet both before and since May, 1934, dust storms have been fairly common in the "Dust Bowl," which includes the states of Oklahoma, Nebraska, Texas, the Dakotas, and Colorado.

In the Dust Bowl, crops are sometimes "blown out of the ground." Sometimes, in the southern part of the Dust Bowl, cotton crops have to be planted two or three times. Can you explain these two statements?

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Knell, from United States Department of Agriculture

In 1935 one county in Wisconsin paid twenty-five thousand dollars for the repair of damage done to roads by erosion. The roads had been either washed out or covered with eroded soil. What other kinds of flood damage are suggested by this picture? **Panel Discussion:**[1] The effects of erosion are more serious than the effects of war

Canada has its Dust Bowl, too, which covers many millions of acres in the prairie provinces of Alberta, Saskatchewan, and Manitoba. Here dust storms were so serious from 1931 to 1937 that the Canadian government began to take measures to halt further soil drifting and to restore the farm land already injured.

[E]There were two principal reasons for such storms in the regions where they occurred: (1) the areas under cultivation were increased, and (2) the cultivated areas were left for so much of the time without a covering of vegetation.

1. At the beginning of the First World War, in 1914, there was an enormous demand for wheat. Farmers greatly increased the amount of their land under cultivation. By 1919, in the United States, there was two and one-half times as much land planted to wheat in the Dust Bowl as in 1914. By 1929 the area had again been doubled. The more extensive the farming in these dry regions, the greater are the opportunities for wind to blow away the top-soil.

2. The Dust Bowl is a region of scanty rainfall. Several years may pass in some sections without enough rain to produce good crops. Many of the farmers plant grain crops with

[1]Page 116.

the hope that there will be enough rainfall to mature them. But when the rains do not come, the crop plants dry up and die, leaving the ground bare. Furthermore, in many sections the farmers keep the ground well cultivated in order to have it covered with a layer of fine soil. Such a layer reduces evaporation and thus holds in the top-soil most of the moisture that already is in the soil. But with nothing to anchor it, the loose soil, especially the humus, is blown from the fields and lost forever.

DAMAGE FROM LOSS OF SOIL · In every province of Canada and in every state of the United States, losses of precious top-soil from erosion by wind, or by water, or by both are constantly occurring. It is estimated that in some areas as much soil has thus been lost forever during the past twenty years as could be produced by the natural processes of soil-making in seven thousand years. In four states alone—Minnesota, Wisconsin, Iowa, and Illinois—thirteen million acres of good farm land has lost most of its top-soil by sheet erosion, and much of this land has been seriously damaged also by gully erosion.

The United States Soil Conservation Service estimates that from the time when the first colonists started farming to the present, about three centuries, a third of the total area used in agriculture and grazing in the United States has been injured by erosion, and that at least fifty million acres has been ruined. Thus as much agricultural land has been ruined as Japan uses to grow crops for her entire population.

DAMAGE FROM FLOODS · The news item on this page calls attention to only one kind of flood damage, namely, that done to farm crops. Such damage consists in covering fertile land with soil and stones or in washing away the top-soil with extensive sheet and gully erosion. But many other kinds of damage also result from floods (illustration, p. 75). These include occasionally the loss of human life, frequently the drowning of farm animals, and always damage to homes and buildings, farm machinery, and many other kinds of property. The American Red Cross always finds need for its services of help and relief wherever and whenever there are floods.

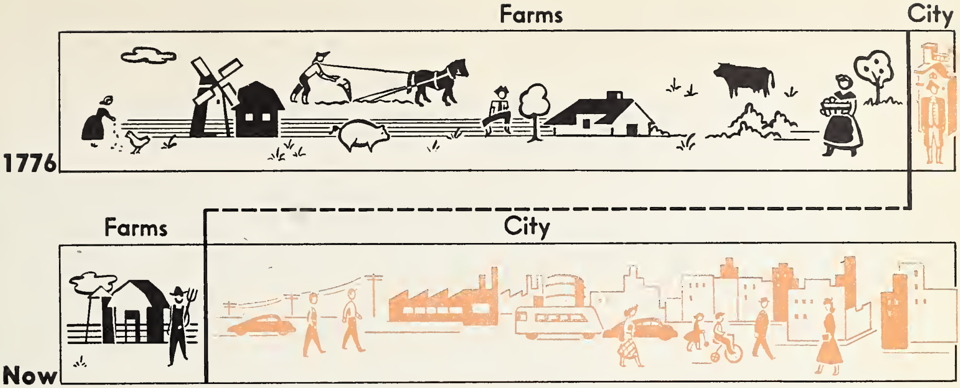
> CHICAGO, ILL., May 10 —The recent general and continued rains have already caused serious floods in several states. Rivers are out of their banks in many localities, and the flood has not yet reached its predicted peak. Thousands of acres of farm land, already planted, has been covered by the water, and the grain crops in these sections will be a complete loss.

Floods do further damage by covering streets and highways and by filling reservoirs, ponds, and harbors with deposits of sediment[1] and silt.*[2] These deposits consist of particles most of which were once fertile top-soil. They not only are a permanent loss to agriculture, but also are the cause of a great expense of labor and money for their removal.

Floods frequently contaminate water supplies. As the water spreads over the land, it is likely to collect disease germs from animal pens, from outdoor toilets, and from sewage, and to carry the germs into springs, streams, lakes, and wells. As a result, serious outbreaks of germ diseases often occur after a flood.

[1]*Sediment* (sĕd'ĭ mĕnt) is composed of solid particles of material, such as particles of eroded rock, soil, and humus.

[2]Silt is made up of minute particles of sediment.



The migration from country to city · Do you expect the proportion of families that live on farms to be greater or smaller in the future than now? Justify your answer

[E]From the facts just presented, it is easy to understand why flood damage is increasing in many sections of the United States. It is apparent that floods are becoming more frequent and more destructive for the same reason that sheet and gully erosion are becoming more widespread and more serious. This reason is the removal of the forests and other soil cover, and the consequent rapid run-off of rain and melting snow.

WHOSE CONCERN? · [E]Is erosion your concern? Do people who live in cities need to be concerned about the erosion of farm land and grazing land? Do people who live in the United States and Canada need to be concerned about erosion that is taking place in other parts of the world? The answer to each of these questions is "Yes." Everybody suffers from the consequences of erosion, no matter where he lives or where the erosion takes place. Here are some of the reasons why this last statement is true:

[E]At the time of the Revolutionary War nineteen out of every twenty families in the United States lived on farms. At the present time only one family in every six lives on a farm (illustration above). The reason why it is possible for most of the families to live in cities is that the farmers have learned effective ways of increasing crop production. If, however, the farm land continues to be eroded, a time will be certain to come when the farmers no longer will be able to raise enough food, in addition to their own needs, either for the people in our own cities or for export. Indeed, many will no longer be able to support their own families.

[E]If farmers are unable to raise sufficient crops, they do not have money to spend for the manufactured things they need which city dwellers make. If city dwellers cannot sell their manufactured products to farmers, they do not have enough money to spend for the things that the farmers raise. Neither group can be prosperous unless the other is also prosperous.

[E]The farm land in Canada and the United States must be kept producing as much food as possible for another reason. Not only must these nations feed their own people, but also they must help to feed great populations

in the countries where the Second World War was fought, until these populations can support themselves.

[E]Saving the soil is a world-wide problem. In India, for example, the land that can be plowed is fast disappearing. In South Africa the greatest problem is erosion. In China vast areas, where once were fertile fields, are now only worthless sub-soil. For many years soil experts from the United States have been in China and Mexico, and in Ecuador, Colombia, Venezuela, and other South American countries, teaching the farmers there, as they are teaching farmers here, how to retain the top soil. Can the world's fertile soil be saved in time? Possibly, possibly not.

3. How Can the Erosion of Top-soil Be Checked?

The Bad Lands region of South Dakota is picturesque and interesting (illustration, p. 68). This extensive area, however, is of no value for agriculture or grazing. It is land from which water erosion and wind erosion have removed the top-soil. It furnishes an example of what would happen to any section if the vegetation that covers and protects the soil were destroyed and erosion were not checked.

RESULTS OF RAPID RUN-OFF · If the speed of the flow of water is doubled, the load of eroded soil that the water can carry is not twice as great as it was before, but many times as great. If the speed is tripled, the carrying capacity is increased not three times, but several hundred times. Also, the greater the speed of the run-off, the greater is the danger of destructive floods.

CHECKING EROSION · In order, therefore, to check soil erosion caused by running water, and also to reduce flood danger, the swift flow of water over the surface of the soil must be prevented. A number of ways of accomplishing this purpose have been invented and are now being widely put into practice. Most of these practices are effective in preventing wind erosion, as well as water erosion.

1. Contour plowing. Wherever plow furrows are level, there is no run-off of rain water in the furrows, and hence there is no sheet or gully erosion. Furrows can be made practically level, even on hilly land, by contour plowing. A contour is a line that follows the same level across a field. Hence it goes around the face of a slope, instead of up and down it (illustration, p. 79).

Contour plowing has been practiced in Europe for generations. Not many people in the United States, however, had heard of it until a few years ago. Yet Thomas Jefferson urged contour plowing, instead of straight-line plowing, about one hundred and fifty years ago. Contour plowing is effective chiefly on land with slight slopes. On hilly farms other methods of checking rapid run-off, described on the following pages, are used along with it.

2. Terracing. Even on gentle slopes the water gains speed as it flows. Hence, in order to reduce the speed of the run-off, terraces are made by building low ridges along the contours or at intervals up and down a slope. Terraces built on a sloping field check the run-off and hold the water.

3. Strip cropping. Strip cropping consists in planting alternate strips of two different crops on slopes where the erosion is likely to be considerable. One strip is planted with a

Soil Conservation Service

Contour plowing with a mold-board plow · Community Application of Biology:
Secure from the United States Soil Conservation Service the bulletin which provides instructions on how to lay off contours. Then lay off several contour furrows on land near the school, in a park, or on a farm

crop such as corn, in rows. The adjoining strip is planted with a close-growing crop, such as hay or a small grain. The covered strips, each about a hundred feet wide, follow the contours around the face of the slope. Thus they slow down the flow of water. Consequently more water soaks into the ground. The vegetation on the strips anchors the soil and prevents sheet erosion of the parts of the field which they cover.

4. Mulch farming. Whenever farm crops such as small grains and corn are harvested, stubble, stalks, and other parts of the plants remain on the ground. Crop residues, or left-over parts, such as these were formerly considered worthless and hence were often burned. Now they are cut up and scattered over the ground by disk plows, and other forms of plows and farm implements, to form a loose covering, or mulch. Mulches are made also by harvesting with a combine harvester. This machine returns the straw to the surface of the field or cuts only the heads of grain, leaving the stalks standing.

Mulch farming protects the soil from sheet erosion by both water and wind. It has other advantages, which will be stated later.

5. Rotation of crops. Crops are rotated by planting a series of two, three, or four different crops in the same field in successive growing seasons, and by then repeating the series as a cycle (illustrations, pp. 100–101). Thus land which has been badly eroded from being planted year after year to corn may be planted to hay, and then to wheat, before corn is again planted. Similarly, a cotton crop may be followed with a planting of clover. The hay, wheat, or clover crop covers the field almost completely and thus protects the soil from erosion by wind and water. Planting corn or cotton in a field only every third year greatly reduces the loss of top-soil.

6. Diversion ditches. A diversion ditch is a wide, relatively shallow ditch which follows a contour around the face of a hill or slope. It is like a great contour furrow. It is often twelve to fifteen feet wide and three feet deep. Grass is grown in this ditch to prevent the erosion of its sides and bottom. Diversion ditches carry off surplus water so that it does not erode the soil.

7. Cover crops. Cover cropping consists in planting a crop to anchor the soil. Often a quick-growing close crop, such as winter rye or wheat, is sown after harvest to hold the soil and thus to reduce erosion by water and wind. In the Dust Bowl one of the first steps toward getting the farms back into cultivation is to plant cover crops to anchor the soil.

8. Discontinuing the farming of some of the land. Parts of many farms are hillsides so steep that serious erosion cannot be prevented if crops are grown on the slopes. Many farmers are providing constant cover for such fields by changing them to permanent pastures.

RECLAIMING GULLIES · Gully erosion is combated by combining various means just described. Contour furrows are often plowed across the slope above the gully and at right angles to it, in order to reduce the amount of water running into it. Sometimes a diversion ditch is built on the slope for the same purpose. Dams are constructed across the bottom of the gully to hold the water and to collect whatever eroded soil it is carrying (illustration, p. 139). To retard (delay) the run-off, the sides of the gully are sloped in the same way as the sides of highways that are cut through hills. The sides and sometimes the bottom are planted to cover crops.

RECLAIMING THE DUST BOWL · When the Dust Bowl was suffering its greatest destruction, between 1934 and 1940, many people thought that that part of the United States was doomed soon to become a barren waste. Many farmers were forced to abandon their homes and to take their families to parts of the country where they would have a chance to make a living.

The United States Soil Conservation Service at once began experimenting to find ways to stop the wind erosion and to restore this once fertile land. In addition to cover cropping, strip cropping, contour plowing, and the various other ways of checking erosion already described, the planting of shelter belts was introduced. Shelter belts consist of parallel rows of closely planted trees.

In the Dust Bowl and other regions where wind erosion is serious, shelter belts are planted to reduce the speed of the wind and to turn the wind upward. The first belt is planted on the edge of the farm toward the direction of the prevailing winds. Later other belts are planted, sometimes at right angles to the first, and sometimes parallel to them or along the contours. Thus the winds are prevented from getting a clear sweep over the land from any direction.

The efforts of the Service have already

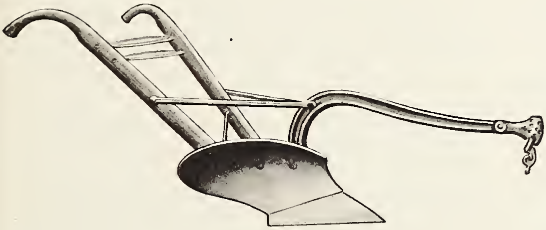
met with considerable success. Much abandoned farm land has already been put back into production. Moreover, there is good reason to hope that if all the farmers would practice the methods of conservation that have proved successful, most of the Dust Bowl could in time be again the fine agricultural area that it formerly was. The great demand for food following the Second World War, however, has caused some farmers in the Dust Bowl to forget or to disregard the lessons learned from the earlier dust storms. They are again putting into practice the former methods of increasing the areas under cultivation and of leaving the cultivated fields bare. As a result, there is danger that much valuable farm land reclaimed or saved from destruction during the ten years from 1935 to 1945 may be permanently ruined.

NEW TYPES OF PLOWS · Thomas Jefferson is given credit for having invented the mold-board plow. This type of plow has long been in almost universal use in the United States.

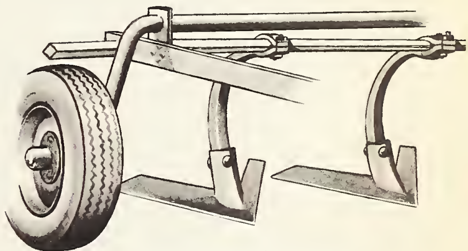
Recently disk plows and several types of sub-surface plows have been coming into considerable use (illustration on this page). The disk plow cuts through the surface, but leaves most of the vegetation there. The duck-foot plow runs along from two to six inches under-ground, and lifts and loosens the soil but does not turn it over.

The mold-board plow is useful in burying humus and pests, such as corn-borer larvae and other larvae. Also, it permits the heavy production of vegetable crops on level ground. It is the only one of the types of plows, moreover, that can be used for making contour furrows, terraces, or diversion ditches.

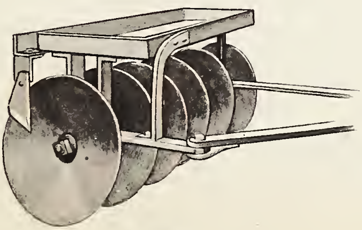
Four types of plows · Bulletin-Board Display: Make a bulletin-board display of pictures showing various types of plows and cultivators. Consult bulletins of the Department of Agriculture and farm magazines



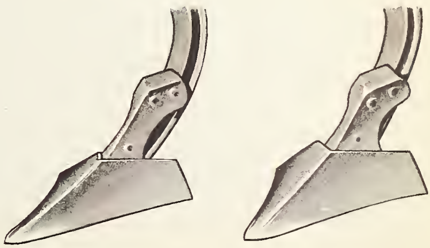
Mold-board plow



Duck-foot shovel, or sweep



Disk plow



Lister plow-shares

The chief disadvantage of the mold-board plow is that it leaves the soil bare. Thus its use is responsible for increasing the rate of erosion by wind and running water.

The disk and sub-surface plows have several advantages: They stir up the soil and kill weeds. They leave a mulch of crop refuse and other vegetation on the top of the ground. The mulch prevents most of the erosion. Also, it greatly reduces the evaporation of water from the soil and thus increases the yield.

Which type of plow is best has not yet been decided. It seems likely that there will prove to be a use for each type, because each performs certain important functions better than any of the others can perform them.

Checking What You Know

BIOLOGICAL FACTS · The test items in the first group below are chiefly of the Completion type. See "This Book and You," p. xv. *(Do not write in this book.)*

Pages 64–71. **1.** The melting of iron is a --?-- change.

2. The souring of milk is a --?-- change.

3. Every chemical compound is composed of two or more of the ninety-two --?--.

4. Minerals are *organic* matter in the soil.

5. Dead plants and animals and their products are the source of --?-- in the soil.

6. Rocks are changed into soil by the process of --?--.

7. The process by which soil is moved from higher to lower levels is known as --?--.

8. The chief agents of erosion are --?--, --?--, and --?--.

9. Top-soil is likely to be removed by the process of --?-- faster than it is produced by the process of --?--.

Pages 71–78. **10.** Name at least two factors that affect the rate at which erosion takes place.

11. In what four ways has man caused more rapid erosion of the soil than would naturally occur?

12. Farming with tractors and other machinery is not possible where extensive *sheet* erosion has taken place.

13. What were the two principal reasons for increased wind erosion in the Dust Bowl area?

14. The top-soil in a field which is almost level is now three inches thinner than it was fifty years ago. There are no gullies in the field. This is an example of --?-- erosion.

15. List six kinds of flood damage.

Pages 78–82. **16.** In contour plowing the furrows run *across* the slopes.

17. The purpose of contour plowing is to make the furrows as *level* as possible.

18. *Weathering* can be checked by slowing down the flow of water.

19. Name three types of plant root systems.

20. In your own words explain the eight ways used to check soil erosion on pages 78–80.

BIOLOGICAL PRINCIPLES · Follow the same directions as those given on page 37.

1. Ninety-two chemical elements make up the earth and all the living things on it.

2. The elements of which the earth and living things are composed cannot be destroyed; they can only be changed from one form to another.

3. The activities of one kind of organism affect the lives of many other kinds.

4. The surface of the earth and the living things upon it are constantly changing.

BIOLOGICAL TERMS

**compound	**element	**mixture
**conservation	**humus	**soil

Applying and Extending What You Know

AS SCIENTISTS WORK AND THINK · **1.** Which of the scientific attitudes (p. 571) are related to the belief that stones grow?

2. Farmers all over the country have been discussing the values of the new kinds of plows, and comparing the new plows with the mold-board plow. Some farmers are trying the new plows; others refuse to do so. Which of the scientific attitudes are possessed or lacked by each group?

3. Which of the scientific attitudes does a farmer not possess who refuses to change from up-and-down plowing to contour plowing, despite the proved advantages of the latter?

4. Suppose that you are a farmer interested in the new kinds of plows. You are not sure what are the advantages of each. How would you find out? Which of the elements of scientific method (p. 570) would you use in finding out?

CONSUMER BIOLOGY[1] · **1.** How may erosion affect the cost of food to the city dweller?

2. Why is the information about different kinds of plows of value to a buyer of farm machinery?

3. Would land that is frequently flooded be good land to buy for a farm or a truck garden? Explain.

APPLYING YOUR KNOWLEDGE OF BIOLOGY · **1.** Some farmers are planting trees on steep hillsides on their farms. Others are planting grasses and using the hillsides as permanent pastures. What are the advantages of these practices?

2. Why have there been no dust storms in the southeastern parts of the United States?

3. A famous scientist has said that one way in which man is superior to all other animals is in his ability to make plans. Most people, however, will make long-distance plans only when driven by pain or fear. Can you explain how these statements relate to conservation?

4. A forest stream is rarely muddy. Why?

[1]Page 38.

5. The lane through which the cows are passing (illustration, p. 61) roughly follows a contour line. How is this location of the lane in harmony with good soil-conservation practice?

TOPIC FOR INDIVIDUAL STUDY · As suggested on page 64, consult a textbook of geology or astronomy to learn what scientists think took place during the early history of the earth

EXPERIMENTS · **1.** How does the amount of slope of a hill affect the rate of erosion by running water? Build or obtain an open-top box about thirty inches square and about four inches deep, with one side lacking. Fill the box as full as you can with top-soil and press and pound the soil down firmly. With a sprinkling can, sprinkle the box of soil while it is in a level position. Does any of the soil wash away? Why? Now tilt the box at a slight angle, with only the bottom edge of the open side resting on the ground, and sprinkle the soil again. What happens now? Next tilt the box so that it is at a steep angle, and sprinkle again. Now what happens? From your observations can you answer the question with which this experiment begins?

2. What is the effect upon erosion of strip cropping? In the box of soil that you used in the preceding experiment, plant grass seeds in strips about three inches wide, leaving a three-inch space of bare soil between each two strips. A few ounces of lawn grass seed will be sufficient for this. The seed which accumulates on barn floors in hay-mows may be used instead. Sow the seed thickly, and cover with soil to a depth of not more than a quarter of an inch. Wet the soil, using a sprinkling can. When the grass has grown to be about two inches high, repeat the preceding experiment. What are the results? Explain.

BIOLOGY OUT OF DOORS · **1. Looking for evidences of soil-making.** Take a walk through a woods. Look for lichens growing on large stones or boulders (illustration,

p. 558). Can you find evidence that the lichens are affecting the rock? If so, what is the evidence? If you do not see such evidence, can you suggest any reasons why you do not?

2. **Determining the depth of the top-soil in your neighborhood.** Dig holes in a field, a vacant lot, a woods, a hillside, a hilltop, and other locations near your home to find out how deep the top-soil is. Keep careful notes. If you find differences in the depth of the top-soil, try to explain them. The editor of your school paper, or even of your town paper, may be glad to publish a report of your findings.

3. **Looking for evidence of erosion.** Look for sheet and gully erosion in your schoolyard, farmer's fields, empty lots, city parks, new lawns, or your own yard. You may not find long, broad, and deep gullies, or deep deposits of sediment. You can, however, find evidence of erosion in almost any area, especially where the soil is bare and especially, also, after a heavy rain. Summarize your observations.

COMMUNITY APPLICATIONS OF BIOLOGY · 1. **Finding out what methods of soil conservation are practiced in your vicinity.** As you go about your community, or travel from one place to another, watch for the use of different methods of soil conservation, such as contour farming, strip cropping, terracing, and cover cropping. Keep a record of these, taking note of the places where you see them. From all the evidence which you find, do you infer that the citizens of your vicinity realize fully the great need for soil conservation? Justify your answer.

2. **Getting expert help on soil conservation.** If you live in a county which has a county agricultural agent, make arrangements for him to come to your school and talk about how soil conservation can be carried on more effectively in your community.

PANEL DISCUSSION.[1] · What benefits have been derived and can be expected from planting shelter belts? Consult the United States Department of Agriculture bulletins *Trees That Temper the Western Winds* and *Tree Planting on the Prairie States Project*, and more recent ones that may be available.

BULLETIN-BOARD DISPLAYS · 1. Collect pictures from magazines, newspapers, and other sources which show examples of erosion. Make a display of these on your bulletin board.

2. Collect pictures of flood scenes from newspapers, magazines, and other sources. Try to find at least one picture showing each of the different kinds of flood damage listed in this chapter. Arrange these in a bulletin-board display.

3. Obtain as wide a variety as you can of pictures showing good farming practices of the kinds which result in soil conservation. Some of the pictures may be reproductions of aerial photographs which are intended to show something else, but which incidentally show strip cropping, terracing, contour plowing, and other conservation measures.

BIOLOGY IN THE NEWS · Clip from newspapers and news magazines items relating to floods, dust storms, the construction of dams to prevent erosion, and other aspects of soil conservation. Make a bulletin-board display of these. Make brief notes of discussions about soil conservation which you hear in radio news and special programs, and of aspects of soil conservation which you see presented in news-reels, so that you can later make a brief but accurate report on them in your class or your science club.

[1]For an explanation of panel discussions see page 116.

4

CONSERVATION OF NEEDED MATERIALS IN THE SOIL

1. How Is Water Lost from and Returned to the Soil?

This item appeared in newspapers all over the United States, on May 25, 1944:

> ALBUQUERQUE, N. M., May 24 (AP)—Rains that came in the nick of time have calmed the old Dust Bowl once more, after its worst season since the days of black blizzards. In 1943 the moisture situation was desperate. In 1943, rainfall was from 25 to 60 per cent below the long-time average for some of the bowl country. In December (1943) and January (1944), the snows came too late to save the wheat crop planted in late fall.

News items such as this emphasize the importance of rainfall in relation to crop growth (illustration, p. 86). Also, they indicate the importance of Dust Bowl crops to everybody, no matter in what part of the country he lives.

RAPID RUN-OFF MUST BE CHECKED · [P]Plants take in the water they need through their roots. Their tops could be kept constantly wet, and still the plants would die if the ground where they were growing should become too dry. Therefore rainfall is of no use to plants unless it soaks into the soil deeply enough to reach the roots.

[E]These facts suggest an important reason

From just what you see in this illustration, can you infer what the water table is? Check your inference by page 87

Cushing

Like all other living things, crop plants cannot grow to maturity without constant supplies of water, because protoplasm is composed chiefly of water. Can you invent an experiment to find out whether soil that looks dry contains water? Do not overlook introducing a control and a check experiment (p. 570)

why a swift run-off of water must be checked, besides the need of preventing the rapid erosion of top-soil and of preventing floods. It is that the rainfall must stand on the soil long enough so that a sufficient quantity will soak into the ground to provide the plants with what they need. A fourth reason is that the under-ground water supply must be maintained.

SOIL WATER · All soil is more or less porous; that is, it is full of openings, such as cracks and tubes. Rain water that enters these openings sinks down through the top-soil, under the constant pull of gravity, just as water in rivers or in the gutters after a rain flows from higher to lower levels.

Only water that sinks into the ground is soil water. Run-off water is not. Water soaks slowly into compact soils, such as clay, in which the pores are minute. It soaks rapidly into loose soils, such as sandy[1] and gravelly soils, in which the spaces between the particles are relatively large.

Some of the water that sinks through the top-soil remains as a film that covers every particle of soil. Even top-soil that looks perfectly dry contains film water. Additional

[1] "This Book and You," p. xiii.

water is held in the top-soil by humus, each bit of which acts like a sponge to absorb and hold water. The rest sinks through the soil and becomes the permanent under-ground water supply.

The under-ground water supply forms a sort of reservoir of saturated[1] soil above the bed-rock. The top of this layer of saturated soil—that is, the level of the under-ground water at any spot—is called the water table (illustration, p. 85). The water table rises toward the top of the ground in wet weather, as the under-ground water supply increases, and sinks during periods of drought, as the under-ground supply diminishes.

NATURAL LOSSES OF SOIL WATER · **By evaporation.** As soon as rain stops falling, the soil begins to lose water that it has absorbed. Some of this water evaporates at the top of the ground. You have probably observed how quickly the surface of freshly spaded garden soil or ground that has been turned over with a plow becomes dry. The water gets to the top of the soil by capillarity,**[2] in the same way that ink will rise in a blotter if a corner of the blotter is held in the ink, and that water will "climb" up a towel if one end of the towel is placed in the water. [P]The smaller the capillaries, the higher the water will rise in them. As fast as water is evaporated from the mouths of soil capillaries, more rises to take its place.

By transpiration. Soil water is constantly passing up through the roots and stems of plants to the leaves, where it evaporates. The evaporation of water into the air from plants is known as transpiration.**[3]

[1]*Saturate* (săt′ū rāt): to fill as completely as possible, as a sponge or a cloth with water.

[2]*Capillarity* (kăp ĭ lăr′ĭ tĭ): the rise of liquids through capillaries. *Capillary*** (kăp′ĭ lĕr ĭ): a small, tube-like opening or pore.

[3]*Transpiration* (trăn spĭ rā′shŭn).

The quantities of soil water that are transpired by plants are enormous (illustration, p. 89). For example, fifty tomato plants in your home garden will not ripen their full crops unless they can take from the soil about fifteen hundred gallons of water during the season. Nearly six hundred tons of water is required to raise enough clover to weigh one ton when dried.

By under-ground drainage. Only part of the rainfall that sinks into the soil escapes from it by evaporation and transpiration. Water from the under-ground supply is constantly draining out of the ground through under-ground rivers, through springs and swamps, and into wells. Thus, in time, most of the water again reaches the surface of the ground.

THE FALLING WATER TABLE · [E]The under-ground water supply varies more or less from season to season. Nevertheless it is expected to remain fairly constant over considerable periods of time. For many years, however, the water table has been falling year by year in many parts of the United States. In some sections of the Middle West it has fallen fifty feet in a hundred years. Here is evidence that the under-ground water supply is becoming exhausted, just as are others of our natural resources.

Causes of the falling water table. [E]The destruction of forests and of the plant cover on farm land, and farming methods which have caused the rainfall to drain away on the surface rather than to sink into the soil, are only partly responsible for this condition. At least two other factors have helped to decrease the stores of under-ground water. These are (1) the use of water in industry and (2) the waste of water by most people.

Illustrations of the first are furnished by the steel mills in one Ohio town, which use

five billion gallons of water per year, and by the large synthetic-rubber plants, each of which requires about seven million gallons per working hour. An example of waste is furnished by almost any large city, which actually uses, for drinking, fire-fighting, and all other necessary purposes, only a small fraction of the water that flows through the mains. The rest flows away through the sewers as the result of carelessness, indifference, and the use of inefficient equipment.

Much of the water used in industry and for general purposes is, of course, secured from rivers and lakes. So much, however, is being pumped from wells that the underground supplies are being used up faster than they can possibly be restored by natural processes, even when aided by practicing the farming methods which cause rainfall to sink into the soil.

WATER CONSERVATION THROUGH FARMING METHODS · [E]Several of the methods used in preventing the loss of soil by sheet erosion are useful also in returning water to the soil. Among these are (1) contour plowing (illustration, p. 90), (2) making diversion ditches, (3) terracing, (4) cover cropping, (5) strip cropping, (6) planting shelter belts, (7) mulch farming, and (8) sub-surface plowing.

Contour plowing, terracing, and making diversion ditches. It has been estimated that in certain parts of the United States enough water to cover five and a half million acres to a depth of a foot runs to waste every year. Much of this water could be saved for crops by plowing the fields along the contours and by providing diversion ditches and terraces where needed. Contour furrows, diversion ditches, and terraces act as reservoirs during a rain. They not only collect the water, but also, because they are fairly level, hold it until most of it can sink into the soil.

Cover cropping and strip cropping. Cover crops and strip crops reduce the amount of water lost from the soil, in two ways: (1) they reduce the amount of bare ground from which water can evaporate, and (2) they reduce the speed of run-off and hence cause more of the water to soak into the soil. On a sloping hillside the loss of water from a strip planted to corn may be several hundred times as great as the loss from the same strip planted to grass.

Planting shelter belts. Wherever the wind has a clear sweep over farm land, the evaporation of water from the surface is much greater than from similar land protected by windbreaks. The planting of shelter belts in the Dust Bowl, by providing wind-breaks, has proved to be an effective means of reducing such evaporation.

Mulching. Mulches[1] conserve water in the same ways that cover crops and strip crops conserve it. The types of plows that make mulches by cutting through the vegetation covering the land, or by loosening the soil beneath the surface without turning it over, help to prevent the escape of moisture which would be lost through evaporation if the soil were turned over with a mold-board plow (illustrations, pp. 79 and 81).

DRAINAGE · There are many localities where the soil is suited to agriculture except that it contains too much water. The drainage of such wet soil is necessary. It is accomplished with ditches or with porous tile laid end to end to form continuous pipes under the soil. The drained-off water can be conserved by directing it into natural or artificial ponds at lower levels.

IRRIGATION · In great areas of the western United States there is too little rainfall for successful crop-growing, although the soil is

[1]Page 79.

Soil Conservation Service

Every fruit tree in an orchard during a summer requires from a thousand to several thousand gallons of water, depending on its size. Can you explain how this statement relates to water conservation?

fertile. If all the methods of water conservation just described were used there, the soil would still be too dry. Water for irrigating such areas is secured by damming rivers and by then bringing the water to the farms through canals and ditches. Twenty million acres have in this way already been changed from deserts to prosperous farms and orchards.

WATER CONSERVATION THROUGH OTHER METHODS · A variety of measures are now being taken in different localities that are not agricultural districts to maintain or raise the water table and thus to avoid a permanent shortage. (1) In some areas no wells may be dug or drilled for any purpose without a special permit from the state. (2) In certain places, during times when there is a surplus of water available, all that is not needed is pumped back into the ground to replace that removed earlier from wells. (3) In Old Bridge, New Jersey, the vegetation covering an area of gravel was removed some years ago. The course of a stream was changed so that it flows over the exposed gravel. In many localities the run-off water and water from streams are directed into abandoned gravel pits. Also, ponds are constructed in gullies and depressions prepared to hold the run-off water that is made to flow into them (illustrations, pp. 92 and 139). By these means far greater quantities of surface water are caused to sink into the ground than otherwise would in these same areas. (4) Low dams

Soil Conservation Servic

Experiments conducted by the United States Department of Agriculture have shown that the water saved by contour plowing, as compared with what would have been lost through up-and-down plowing, has increased the yield of potatoes more than 40 bushels per acre; of corn more than 20 bushels; of wheat 4 bushels; and of cotton nearly 30 pounds. Can you suggest how such experiments as these might be carried out (illustration, p. 95)?

are built across the outlets of shallow lakes, which are common throughout the territory once covered by the Great Ice Sheet—all the Canadian provinces, together with Minnesota, Michigan, and other states. These dams help to prevent the water in the lakes from falling below desired levels. (5) In many cities where, earlier, people paid a flat rate for water and were allowed to use as much as they pleased, meters have been put into use and water rates have been raised in order to discourage waste. These measures have in some cases reduced by one half the amount of water used. (6) In many places people are not permitted to use water for their lawns and gardens during parts of the summer. (7) In a few places water has been rationed.

E It is by no means certain whether all the conservation measures now practiced have been begun in time and are being practiced widely enough to maintain an underground water supply which will be ample for industry, sanitation, irrigation, and all the other common and increasing needs.

2. Why Are Minerals Important in the Soil?

After the early colonists of the United States and Canada had become established on the eastern coast, the populations of the two countries began to spread westward. Explorers, hunters, trappers, and missionaries pressed into the wilderness. They were followed in time by settlers.

The settlers changed the wild land to farms. They planted the same crops on the same land year after year. The possibility that the soil might become exhausted probably did not occur to many of them. Where the land was fertile, the farmers got good yields for a while. But all the time the crop plants were taking minerals[1] out of the soil. They were exhausting the crop-land.

LOSS OF SOIL FERTILITY · Not all the loss of minerals from the soil results from their removal by crop plants. Some is due to leaching. Soil-leaching is the process by which minerals are dissolved out of the top-soil by the water that seeps, or soaks down, through it. A process similar to soil-leaching is coffee-making—letting boiling water sink through ground coffee beans to dissolve out the desired substances. The amount of soil-leaching is increased by plowing and cultivating, because breaking up the soil exposes more of its surface to the soil water.

Still further loss of soil fertility results indirectly from the force of falling rain-drops. As they splash upon cultivated ground, rain-drops separate tiny soil particles from larger sand grains. These fertile particles are then more readily eroded away by running water or wind. In striking the ground, rain-drops may also knock minute mineral particles from bits of humus. These mineral particles are then more readily leached out of the soil.

[1]Footnote 2, p. 66

Thus the process by which exposed soil is broken up by the force of falling rain-drops[2] indirectly makes farm soil less capable of producing crops, even though it is protected against erosion.

RESULTS OF LOSS OF SOIL FERTILITY · Because of continued erosion and soil exhaustion, the crop yields obtained by the early settlers decreased. Year by year there were fewer and fewer bushels per acre. When the yields became so small that the farmers could no longer make a good living on their land, those that could do so migrated westward to find new land (illustration, p. 93). This they proceeded to farm by the same methods which they had always used. Hence they exhausted the new land, as they had the old. The ones that could not migrate continued to exhaust the soil of their worn-out farms, and thus to become poorer and poorer. Farmers had not yet learned the all-important lesson that big crops are less important than continued yields.

[E]We are now facing the situation that the peoples of Europe and Asia have faced for centuries. Almost too late we realize that taking minerals and compounds of nitrogen from the land, instead of borrowing them from it, ruins farm land as surely as does unchecked erosion. Unless we pay back into the soil the substances that farming takes from it, we shall sooner or later face starvation.

HOW WE GET MINERALS FROM THE SOIL · Protoplasm is made up of at least twenty elements. These elements are chiefly carbon, hydrogen, oxygen, and nitrogen. In much smaller quantities are sulfur, phosphorus,

[2]This process is known as *elutriation* (p. 72).

Osborne, from United States Department of Agriculture

A farm pond in Alabama · Hundreds of artificial ponds have been made in the Southern states. Summarize the advantages to be gained from constructing such ponds

calcium, and potassium. Still other elements are present in protoplasm as mere traces, but these elements are nevertheless essential.

Plants can secure practically all the elements they need for building their protoplasm, from the minerals dissolved in the soil water. We can secure those that we need by eating plants or by eating other animals that have eaten plants.

HIDDEN HUNGERS · Some years ago large horses from England were pastured on the Falkland Islands. In three or four generations their full-grown descendants were no larger than Shetland ponies. These under-sized horses were moved to the original pastures of their ancestors in England. In a few more generations their descendants were as large as the original stock had been.

E This race of horses became smaller on the Falkland Islands because of a "hidden hunger." A hidden hunger is a form of malnutrition[1] or faulty nutrition due to the lack of some necessary substance or substances in the diet. Such a lack results in poor bodily

[1] *Malnutrition* (măl nū trĭsh′ŭn).

development or in certain diseases. Such diseases are known as deficiency diseases. It is possible to have a sufficient quantity of food and yet be improperly nourished because the food does not contain enough of all the minerals, vitamins, or other substances that the body needs.

HIDDEN HUNGERS AND THE SOIL · [E]Hidden hungers are nearly always closely related to the soil. If the soil lacks essential minerals, then the plants grown in it will have insufficient quantities of the elements that they need for building their various compounds. If the plants lack these essential elements, then the people and other animals that eat these plants will lack them too.

In the case just cited the plant forage on the Falkland Islands lacked calcium compounds because the soil there lacked these compounds. Without calcium the horses could not develop proper bone structures. The forage grown on the pastures in England, to which the horses were returned, were rich in calcium compounds because the soil contains them in abundance.

Many examples of the results of hidden hungers could be given. The plant diseases called "damping off" and "potato scab," as well as certain other fungus diseases of plants, are likely to be more common and severe where there is a lack of calcium compounds in the soil. The disease of live-stock known in parts of Texas as "creeps" or "loin disease," and in parts of Alabama as "creeping sickness" or "sweeny," occurs where there is a lack of phosphorus compounds in the pasture soil. Cows pastured on land poor in compounds of phosphorus and calcium have been observed to produce fewer calves than cows normally produce.

If our diet does not provide enough phos-

An abandoned farm on exhausted soil · How is this picture related to the statement that farming is one important aspect of man's struggle for existence?

Library of Congress

Why calcium is necessary

phorus compounds, as well as calcium compounds, our bones and teeth will not develop properly. Also, if our food lacks calcium compounds, we are usually more nervous and more easily irritated than normally, and our blood clots less quickly when we cut ourselves. If our food fails to supply enough iron and copper compounds of the right kinds, we may suffer from a blood disease called anemia. There are several "goiter belts" in the United States, where cases of goiter[1] are common because the soil does not contain enough iodine compounds to supply human needs through the food that is grown there and through the drinking water.

[1] *Goiter* (goi'tẽr). Page 291.

What evidences of rickets do you see here? (See also illustration, p. 296)

United States Department of Agriculture

Rickets, a disease of childhood, in which the bones do not develop normally, is caused chiefly by a lack of vitamin D[2] (illustration on this page). But it has been found that calves fed on milk from cows pastured on land that lacks calcium compounds will develop rickets, even though they secure enough vitamin D in their diets.

How greatly fruits and vegetables grown in different localities may vary in the quantities of mineral substances which they contain is illustrated by the following examples. A cabbage grown on soil in which there is abundant lime (calcium carbonate) may contain four times as much of calcium compounds as one grown on soil lacking in lime. Spinach grown on suitable soil may contain thirty times as much of iron compounds as spinach grown on unsuitable soil. A lettuce plant grown on soil rich in lime may contain sixty times as much of calcium compounds as a similar lettuce plant grown on soil that lacks lime. Unfortunately, however, nobody can tell from the look of fruits and vegetables whether they contain large or small amounts of the minerals that they are expected to contain.

COMBATING HIDDEN HUNGERS · Some diseases caused by hidden hungers can often be successfully prevented or cured by adding the needed compounds directly to the diet. It has been found, however, that man and other animals are able to make better use of the minerals that their bodies need when they secure these minerals as parts of their foods than when they take them as extra substances to supplement an insufficient diet. Hence the proper place to begin to solve many problems of malnutrition is the soil, through its conservation and improvement.

[2] Page 207.

3. How Can Mineral Substances Be Restored to the Soil?

Did you ever examine a handful of soil to see what you could find out about it? Get a double handful of soil from anywhere in the woods, from under the trees in the park, or from your garden. Examine it with a hand lens or a reading glass. What do you see?

Here are tiny rocks of several kinds and bits of clay or other kinds of soil. You would expect to find these because soil is formed by the weathering[1] of rock. These are inorganic[2] materials.

Here are many bits of leaves. Here are a nut and several other seeds. Here are a part of a plant stem and some small pieces of roots. Here is a dead beetle, there a dead millepede (illustration, p. 531). Here are a piece of bone, a bit of hair, and a feather. All these are organic[2] materials.

What else is in your handful of soil? Nothing else, perhaps, that you can see, even with the reading glass. Yet the apparently lifeless material that you hold in your hands contains a population of micro-organisms, perhaps greater than the population of people in the world's largest city. If you could see these micro-organisms, you would find that they include bacteria,[3] cells of molds and other fungi, protozoans, roundworms, and a great variety of other plants and animals. These organisms, which make up the society of living things in the soil habitat, are engaged in a constant struggle for food, just as are the members of any other plant or animal society in any other habitat.

Among these unseen inhabitants of the soil are some of the most important of all living things because they make possible the existence of green plants. Consequently

[1]Page 64. [2]Page 29. [3]Page 277.

This picture illustrates a government experiment to determine the need for certain minerals in crop land. Which of the steps under "As Scientists Work" (p. 570) are illustrated here?

United States Department of Agriculture

Chamber of Commerce, Honolulu

Making poi in the Hawaiian Islands · The dried root of the taro plant is made moist with water and is then pounded and kneaded into paste (poi). Poi is one of the best sources of calcium in the diet. How do you account for the fact that the taro root contains so much calcium?

they make possible, indirectly, the existence of all animals, including man.

SOIL BACTERIA · About four fifths of the atmosphere is nitrogen. All living things require nitrogen for building protoplasm. Yet none of the higher plants, and not any of the animals, can use the element nitrogen as it exists in the air. It must first be combined with the elements oxygen and either potassium or sodium, to form compounds called nitrates.*[1]

[1]*Nitrates* (nī′trāts).

Certain kinds of soil bacteria can make nitrates. These are the nitrogen-fixing bacteria and the various kinds of bacteria which take part in the processes of decay. Plants use the nitrates resulting from the life activities of these soil bacteria.

NITROGEN-FIXING BACTERIA · The nitrogen-fixing bacteria can take directly from the air in the soil the nitrogen that they need for making nitrates. When pod-bearing plants, or legumes,[2] such as peas, beans, lespedeza,

[2]*Legume* (lĕg′ūm).

clover, and alfalfa, are planted, the bacteria enter their roots through the root hairs. The plant grows around the colonies of these bacteria, forming knob-like swellings (called tubercles[1] or nodules[2] (illustration, below). A single swelling may contain many thousands of nitrogen-fixing bacteria.

The plant and the bacteria form a partnership of the kind known as symbiosis.*[3] In symbiosis each organism is of value to the other. By being partners, both are able to survive more easily than either could alone. Thus, in a partnership of nitrogen-fixing bacteria and a legume, the bacteria profit by gaining a protected habitat within the plant roots and by securing some of their food from the sap of the plant. The plant profits by using the surplus nitrates which the bacteria manufacture beyond their own needs.

[1]*Tubercle* (tū′bẽr k'l). [2]*Nodule* (nŏd′ūl).
[3]*Symbiosis* (sĭm bī ō′sĭs). Each partner is known as a *symbiont* (sĭm′bī ŏnt).

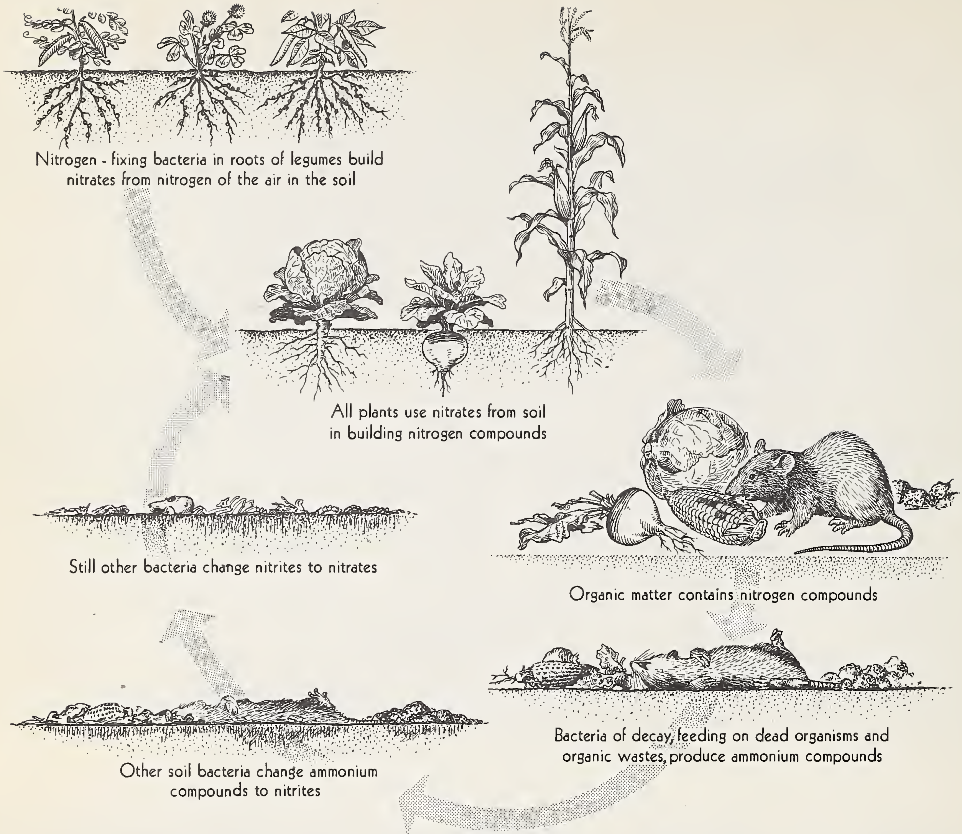
Different species of nitrogen-fixing bacteria form their partnerships with different legumes. Hence, to ensure abundant quantities of nitrates for their pod-bearing crops, farmers put preparations containing the proper kinds of bacteria on the seeds or into the soil before the planting.

BACTERIA OF DECAY · The bacteria of decay and a few other kinds of fungi feed upon organic matter, such as the bodies of dead animals and plants, and nut-shells, manure, and other plant and animal products. In so doing, they change these complex organic materials into simpler compounds composed of nitrogen and other elements. Other kinds of bacteria carry on later stages in the proc-

Tubercles on the roots of pea plants · What sort of partnership would this be if the bacteria, instead of helping the host plant, injured it? if neither the bacteria nor the pea plants helped or harmed the other[4]

[4]Page 513.

Forsythe, from United States Department of Agriculture; Hugh Spencer



The nitrogen cycle · How would you explain this diagram to a boy or girl of your own age who had never heard of the nitrogen cycle? Can you find one or more principles on page 100 which this diagram illustrates?

esses of decay. Finally the organic materials are changed not only to simple nitrates, but also to compounds of all the other elements besides nitrogen which make up protoplasm. These compounds make possible the growth of more plants.

THE NITROGEN CYCLE · If it were not for the bacteria and other organisms that cause decay, a time would come when no more plants and animals could be produced. The reason they could not is that all the available materials needed for their production and growth would already be parts of living or dead organisms. As it is, there is a constant exchange of these materials (illustration above).

E Living things die, and their bodies are reduced by bacteria and other non-green plants[1] to simple compounds that higher plants can use. Plants use these compounds

[1]Footnote 5, p. 45.

to build protoplasm. Whenever plants are eaten by animals, some of the substances composing the plants' bodies become parts of the animals' bodies. Thus the materials that compose living things are constantly in circulation. They have been used over and over, times without number, since life first began on the earth, and they will continue to be used over and over in the future.

The part of these constantly repeating processes which includes the building up and breaking down of nitrogen compounds is called the nitrogen cycle. The nitrogen cycle, however, keeps not only nitrogen in circulation, but also carbon, sulfur, phosphorus, and other elements as well.

KEEPING THE SOIL FERTILE · There are a number of effective ways of putting back into the soil the substances taken out of it by growing crops. These methods include (1) plowing into the soil manure, and stubble, plant stalks, and other plant refuse; (2) plowing into the soil "green manure" in the form of cover crops; and (3) growing legume crops on the soil. Without the action of the soil bacteria, however, as already explained, none of these methods would be in the least effective.

Compounds of calcium, phosphorus, potassium, and some other substances necessary to plant growth can best be restored to the soil by adding commercial fertilizers—for example, powdered limestone or bone meal. Nitrates also can be supplied by commercial fertilizers, but this source is much more expensive than animal manure. And animal manure is more expensive than green manure. Plowing under cover crops of legumes adds not only the nitrates formed by the nitrogen-fixing bacteria living in the plant roots, but also those formed by the decay of the plants themselves. The Romans discovered that planting pod-bearing crops made the soil more fertile, but they did not discover why it did.

CROP ROTATION · Crop rotation is practiced extensively as a means not only of preventing erosion, but of enriching the soil (illustrations, pp. 100–101). When crop rotation is practiced, the amounts and kinds of minerals taken from the soil each year differ. If one of the plantings in the rotation is a legume crop, such as alfalfa, kudzu, soybeans, vetch, or clover, not only is it valuable in itself, but it pays back nitrates to the soil.

Some of the values of crop rotation are evident from these facts: crop rotation has been observed to increase cotton yields as much as four hundred pounds per acre, corn yields by sixteen bushels per acre, and wheat yields by six bushels per acre. Other, similar facts are numerous.

Checking What You Know

BIOLOGICAL FACTS · (*Do not write in this book.*) **Pages 85–90.** **1.** Protoplasm is composed chiefly of __?__.

2. Plants use *chiefly* the water that has soaked into the soil.

3. During a drought the water table (1) rises; (2) falls; (3) remains unchanged; (4) reaches the ground surface; (5) reaches bed-rock.

4. The *greater* the amount of humus in the soil, the *smaller* is the amount of water that the soil will hold.

5. State four causes of the diminishing supplies of underground water.

6. Farming methods that aid in the conservation of soil water by preventing surface evaporation are __?__, __?__, __?__, and __?__.

Two photographs of the same land in two different years · The crops rotated here are

7. State four farming methods that aid in the conservation of water by causing more water to sink into the soil.

8. Of the six other methods of conserving water, besides farming methods, the one that you can yourself put into practice is __?__.

Pages 91–94. 9. Two ways in which the soil on the early settlers' farms became exhausted were __?__ and __?__.

10. *Malnutrition* may be due to a lack in the soil of elements necessary in our diet.

11. Hidden hungers result in diseases of *animals* and people *but not* of plants.

Pages 95–99. 12. *All* green plants are able to use nitrogen taken directly from the air.

13. Certain bacteria can combine *nitrogen* and *oxygen* with potassium or sodium to form nitrates.

14. Nitrogen-fixing bacteria are associated with pod-bearing plants, called __?__.

15. *Nitrogen-fixing* bacteria return substances in the bodies of dead organisms to the soil.

16. The continuous use of substances by living things in the building up and breaking down of nitrogen compounds is known as the *oxygen cycle*.

17. Three ways of restoring nitrogen to the soil are __?__, __?__, and __?__.

BIOLOGICAL PRINCIPLES · 1. Land plants depend on soil water for all the water that they use.

2. Water is lost from soil by evaporation, transpiration, and underground drainage.

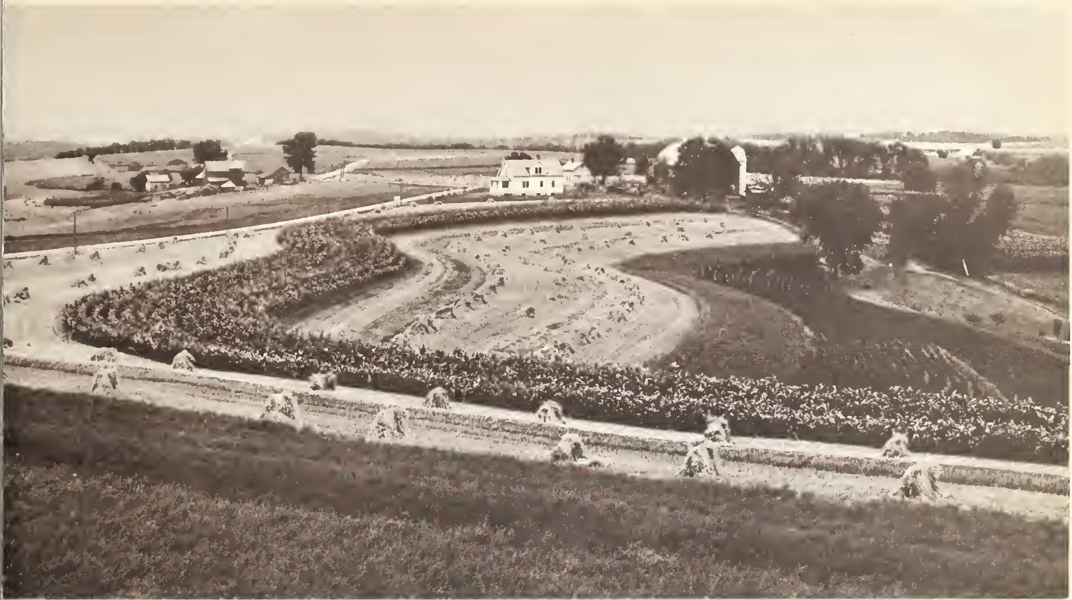
3. Plants that grow in soils lacking in sufficient quantities of certain essential minerals will fail to contain their normal quantities of these minerals.

4. Chemical action brought about by certain kinds of bacteria restores to the soil certain chemical elements taken from it by living things.

5. The materials that compose the bodies of plants and animals are used over and over in endless succession.

BIOLOGICAL TERMS

**capillarity **conservation **transpiration



Soil Conservation Service

corn, leguminous hay, grain, and potatoes. Is crop rotation always a cycle? Explain

Applying and Extending What You Know

AS SCIENTISTS WORK AND THINK · 1. A man who was preparing his garden for planting was heard to say: "Commercial fertilizers are not good for the soil. No matter what the experts say, I will not use them. I tried them once, and they seemed to do no good; so I'll never use them again. They dry out the soil, and I don't like them. They just aren't according to nature." Which scientific attitudes (p. 571) did this man lack?

2. Suppose that the man whose remarks are given in the preceding paragraph is your neighbor. Suppose that you too have a garden, have used fertilizers, and have grown abundant crops. How would you go about convincing your neighbor of the value of commercial fertilizers? Plan an experiment, using the elements of scientific method (p. 570), which you think should convince the neighbor. The illustration on page 95 will probably be of help to you in planning the various steps of your experiment.

3. Can you invent an experiment in which you use sand and salt to illustrate how leaching might occur in soil?

CONSUMER BIOLOGY · 1. Why is it good economy to pay higher taxes in order to have everything possible done to maintain the water table?

2. How do hidden hungers in animals that are used for meat affect our food supply?

3. In what ways might a lack, in the soil, of minerals necessary for crops cost city dwellers money indirectly?

4. Why should city dwellers be concerned about whether the farmers maintain the fertility of their soil?

APPLYING YOUR KNOWLEDGE OF BIOLOGY · 1. Which is likely to be of greater benefit to plants, a two-inch rain which falls in two hours or a two-inch rain which falls in two days? Why?

2. A man was draining a field in which the soil was always too wet. He put the drain tiles six feet below the surface. Two years later he dug up the tiles and put them back in his field at a depth of three feet. Can you give a reason which may explain why he did this?

TOPICS FOR INDIVIDUAL STUDY · 1. Use a geography textbook or an encyclopedia to learn the sources of various commercial fertilizers, such as nitrate of soda, phosphates, and potash.

2. From an encyclopedia or a chemistry textbook try to find out how fertilizers such as ammonium nitrate and calcium carbonate are made, and how nitrates are made from nitrogen in the air.

EXPERIMENTS · 1. How much water does a certain dripping faucet waste? In 1944 the mayor of one of America's largest cities called upon the citizens to repair all leaking water faucets in their homes, in order to conserve water. Is there a dripping faucet in your home? If there is, put a quart bottle under it to catch the water. How much time is needed to fill the bottle? How much water does this one faucet waste in twenty-four hours? How much water might thus be wasted in one thousand homes in twenty-four hours, if each had one faucet leaking at the same rate? How much water would be wasted in a year?

2. What are the characteristics of the nodules on the roots of leguminous plants, or legumes? Find some growing legume, such as clover, sweet clover, alfalfa, soybean, red clover, alsike clover, cowpea, vetch, bean, or pea. If the soil is damp and soft, carefully pull up the plant by the roots. If the soil is hard and dry, use a trowel to dig up the plant. Carefully wash away the soil that clings to the roots. Do you find the nodules which show that nitrogen-fixing bacteria are present? Are there many nodules or few? What is their appearance? If there are none, what hypothesis should you suggest to explain their absence?

COMMUNITY APPLICATIONS OF BIOLOGY · **1. Investigating the quantities of water used by your towns-people.** If you live in a city or town, find out the source of the water supply. Also, find out whether the charge for water is a flat yearly rate or whether it varies with the quantity of water used as measured by a meter. Learn what the charge is. If possible, find out what is the average total quantity of water used daily. In one large city water is used at the rate of almost 200 gallons per person per day. How does this quantity compare with that used per person in your city? Find out also whether there are any restrictions on the use of water, or whether everyone is allowed to use all he pleases.

2. Investigating the rural water supply. If you live in a rural area where water is obtained from wells, find out how far it is from the surface of the ground to the water table, or level of the water in your well. Compare this distance with the corresponding distances in your neighbors' wells. Has the level of the water in your well always been the same? If not, what do you think has caused it to vary?

3. Investigating what is being done in your community to maintain soil fertility. Do gardeners, farmers, nurserymen, and others in your community use green manure? If so, what crops do they plow or spade under? What kinds of commercial fertilizers do they use? What minerals needed by plants are in these fertilizers? What percentage of each mineral is present? How much of each kind is used per square yard or acre? How often is it used? Have you used commercial fertilizer on your lawn, or in your flower beds or vegetable gardens? What did it contain? How much per square yard did you use? How and when did you apply it? What evidence have you that the use of the fertilizer improved the growth of the plants?

5

CONSERVATION OF FORESTS

1. *How Are the Forests Important to the Nation's Welfare?*

In the early days, when a pioneer family made its home in the forest, it found readily available most of the things needed to maintain life. There were abundant fish in the streams, many kinds of game animals all about, and fruits and nuts in season, to serve as food. There were fur-bearing animals to supply outer garments for winter. There were trees to furnish logs for constructing the house and its crude furniture, for building shelters and pens for the domestic animals, and for making fences (illustration below). There was unlimited wood for fuel.

In this way the forest provided the pioneers with food, shelter, and other necessities and also with some comforts. But at the same time it was a constant source of danger to their safety and welfare. Large wild animals, such as bears and panthers, preyed upon the pigs, horses, cows, and other farm animals.

The family who built this wilderness home followed good conservation practices in getting the logs to make the house. Explain

United States Forest Service

NATURE FIRSTS

ARE YOU one of those persons who watch for the first "signs" of spring or for "signs" of approaching winter? Perhaps you have listened for the first song sparrow, early in March, or have watched for the new leaves on the peach and apple trees or on the perennial plants of the flower garden. What you will watch for will, of course, depend on the part of the United States or of Canada in which you live. But in any locality you will find abundant "signs" of the changing seasons by observing the plants and animals near your home.

Many naturalists keep records of the "firsts" in nature as these occur throughout the year. They keep notebooks in which they write the date when they first see a robin, or ducks or geese of the spring migrations, or the "first" muskrat, woodchuck, snake, or turtle out of hibernation.

Why not become such a naturalist? In a notebook you can record the earliest date in the spring when you hear the musical notes of the frogs called "spring peepers." In many parts of the United States and of southern Canada, their "song" may be heard early in April. You can set down the date when you first see a dandelion, a cotton, or a cactus plant in bloom. You can make similar records of when you first see mosquitoes, flies, and certain moths and butterflies in the spring. Later you can write the date when you first observe that the corn plants are "tasseling out" or that the figs or pecans have become ripe. You can record when the winter wheat ripens, when the oat or the rice crop is harvested, and when other wild or cultivated crops are gathered.

There is practically no limit to the number and variety of such "signs" of the passing seasons that a naturalist may record. If you keep such records throughout many years, or if the members of succeeding biology classes "pool" their observations, in time a "nature almanac" can be assembled. With a nature almanac the seasons of the year can be identified not by the calendar, but, more truly, by what is happening to the plants and animals of the locality.

Sargent

Boys and girls who live in great cities will find good opportunities to look for "firsts" in the city parks. Lists and descriptions of "firsts" would make an excellent display for the bulletin board or a science fair

United States Forest Service

What bad practices, from the standpoint of conservation, are illustrated here?

They occasionally attacked even the people. Smaller predators, such as weasels and skunks, killed the poultry. Deer and sometimes bears raided their crops.

To reduce the danger from wild mammals[1] and to secure land for garden and farm crops, the pioneers cut down the forests immediately surrounding their homes. In order to clear the land quickly, the settlers cut, slashed (cut off tops and limbs), and burned without thought or concern for anything but their own immediate welfare.

THE DESTRUCTION OF THE FORESTS · As the United States became more thickly settled, the forests were destroyed at a tragic rate. Timber areas were cleared to make room for towns and farms. Lumbering interests secured vast tracts and proceeded to cut down the trees and remove the logs in the ways that would enable them to make the most money and to make it in the shortest time.

It should be said, however, in fairness to these interests, that in the early days of the nation people did not blame them for their wasteful practices. On the contrary, the average citizen encouraged the rapid production of lumber, timbers, and poles because these forest products were needed at once for building houses, railroads, furniture, telegraph lines, ships, and all the other wooden products that the rapidly growing nation demanded. Consequently the lumber companies logged off the larger trees without

[1]Page 547.

thought or care either for the young trees or for the land where the forests stood. They left the tree-tops, limbs, and other slashings on the ground (illustration, p. 106). When these loose materials became dry, fires started in them readily and spread rapidly. Fires burned over many areas so often that the humus in the ground was destroyed. As a result, young trees could not grow there to replace the burned timber.

The rapid waste of our forest resources continued for many years. Yet few people were disturbed by it until recently. Many thought that the forests were so vast that they could never be exhausted. Others, who were not directly affected by the wholesale cutting of the timber, either did not realize what was happening or did not care. It should be remembered, too, that cutting off the timber provided the only ways of making a living that many people had.

Finally, however, when it was almost too late, more and more people came to appreciate the value and importance of our rapidly vanishing forests. More and more people came to realize that these natural resources justly belonged to future generations as much as to the present one. Laws were passed which placed much of the remaining original, or virgin, forest under public control and protection.

VALUES OF FORESTS · **1. Providing wood products.** If it were possible to list all the articles made from trees, such a list would fill many pages. You can doubtless think of many such articles. The number of the uses of wood is believed likely soon to be enormously increased by a newly discovered process of treating wood with urea.*[1] Urea is a nitrogen compound which is probably most familiarly known as a waste product given off by the kidneys of higher animals. The urea used in the wood-treating process, however, is made from carbon dioxide and ammonia. By this process soft-woods, many of which previously had little commercial value, can be made hard, can be rendered fire-proof and water-proof, can be shaped into any desired form, and can be dyed any desired color.

2. Aiding in flood control. As was indicated earlier, there is no rapid run-off of water in areas covered by trees. The rain is checked in its fall by the tree-tops and the branches. Hence, instead of striking the ground directly and often violently, it runs down the tree trunks and also drips upon the forest floor. The ground beneath the trees is covered, usually to a considerable depth, with decaying logs, branches, leaves, and other forms of humus. This layer of humus absorbs the water and allows it to sink slowly into the ground and to become soil water. Hence it increases the underground water supply and raises the water table.[2]

As a result, the water from rains reaches the streams gradually and some time after the rains have occurred. Therefore, in general, streams running through forests change slowly in volume. Also, they do not vary greatly in flow between seasons of heavy rainfall and seasons of drought.

In contrast, whenever, as a result of logging operations, the forest floor becomes exposed directly to the rainfall, the humus there is rapidly eroded. When this protective covering has been removed, the top-soil is eroded in its turn.

Whenever a forest is destroyed by fire, the ruin of the land is even more rapid and complete than when the trees are logged off. The humus is largely burned up by the fire, and hence the soil is exposed at once to erosion.

[1]*Urea* (ū rē′*ȧ*).

[2]Page 87.

Furthermore, the fine particles of ashes clog the soil capillaries, thus reducing the amount of water that sinks into the ground and increasing the speed of run-off and the danger of floods.

3. Maintaining the water supply. By regulating the flow of water in streams, the forests not only tend to prevent floods, but also help to maintain a constant water supply. Thus, in long dry seasons, they help to ensure enough water for household purposes, for the watering of lawns and gardens and the irrigation of farms, for power and manufacturing plants, and for many other uses which would have to be reduced or stopped if the water in the streams became too low.

4. **Providing homes for wild life.** The forests are the natural homes of many varieties of living things. Whenever a forest is destroyed, the wild animals that inhabit it are no longer able to find food, shelter, and safe places where they may rest, sleep, and rear their young. Hence they migrate in search of suitable habitats or they die. Plants cannot migrate. Hence, even though they should not be destroyed along with the forest, they rapidly disappear. The reason why they do is that they cannot successfully carry on the struggle for existence in their changed habitats.

5. See the illustration and legend on page 109.

2. *How Are Forests Destroyed, and How May They Be Conserved?*

Forest trees are the oldest living things. The General Sherman sequoia, in Sequoia National Park, California, is estimated to be more than four thousand years old. Millions of forest trees in the United States and Canada were centuries old before any colonists migrated to the New World.

E The slow growth of trees makes the waste of our forests especially serious. Virgin forests that have been destroyed could not be replaced in several centuries. From sixty to one hundred years are required to grow a crop of forest trees of a size large enough for profitable harvesting. It is easy to understand, therefore, that unless the present forests are made to last until young trees have had time to replace those that have been destroyed, future generations of our citizens will have to learn how to get along, in large measure, without wood.

FOREST ENEMIES · Forest trees, like all other living things, have many enemies, against which they must constantly struggle for survival. In practicing conservation we are serving as allies of the trees in their struggle to resist these enemies.

1. **Fire.** In a single recent year there were more than two hundred thousand forest fires in the United States alone (illustrations, pp. 46 and 110). They burned over an area of more than thirty million acres and caused an estimated loss of more than forty-six million dollars' worth of timber. To this loss must be added others caused by these fires, which cannot be estimated, but which are perhaps even more serious than the destruction of the timber: (1) the loss of soil fertility resulting from the destruction of the forest humus; (2) the subsequent (later) losses caused by changes in stream flow and

United States Fish and Wildlife Service

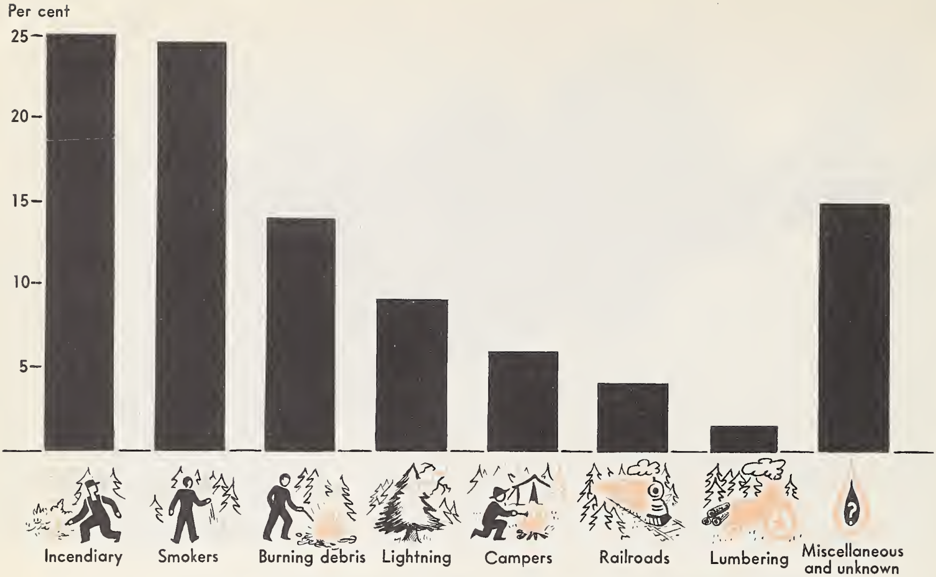
5. **Providing recreation** · Forests furnish ideal opportunities for enjoying nature. Hiking through the woods and observing the plant and animal inhabitants in their natural homes give rich rewards in health and pleasure. **Bulletin-Board Display:** Collect pictures of forest-dwelling birds, such as these young magpies, from magazines and newspapers for a bulletin-board display. Perhaps you can make a similar display of photographs taken by yourself and your classmates

by floods; (3) the subsequent losses resulting from the sheet and gully erosion of top-soil in the burned-over areas; (4) the loss from the destruction of natural beauty and places for healthful outdoor recreation; and (5) the loss of valuable plants and animals both by burning and by the destruction of their natural homes.

The United States Forest Service and the Dominion Forest Service (Canada) provide fire protection in many effective ways. They work with the state and provincial governments to maintain fire prevention and fire-fighting services during the seasons when forest fires occur. Fire wardens constantly patrol the public-owned forests. Trained look-outs stationed in towers and on mountain-tops keep alert watch to discover fires. Fire-fighters trained in all the latest and best methods of controlling fires are constantly available (illustration, p. 111).

2. **Some commercial interests.** Many citizens are now awake to the dangers of forest destruction. Nevertheless most of the lumbering is still done by wasteful methods. The harvesting of the timber is still commonly carried on in ways that bring the greatest immediate profit rather than in those that ensure a sustained yield. Too often no effort is made to leave the cut-off areas in condition to produce another growth.

Fortunately for the future of the forests, about 40 per cent of the timber still standing in the United States is owned by the state



This illustration shows the relative numbers of forest fires due to various causes, in the United States, during a single year. The greatest number, 25 per cent, were incendiary fires, that is, those set purposely. Can you choose the numbered part which will make the following statement correct? Of the forest fires whose causes were known (1) none, (2) all, (3) more than 70 per cent, (4) at least three fourths, (5) less than half, were caused by people

governments and the national government. Furthermore, the Federal government and several of the state governments are steadily adding to their holdings. It is encouraging to note, moreover, that a large and growing number of commercial forest industries and of individual owners are now managing their timber-lands so as to maintain a sustained yield.

The public forests and many privately owned areas are maintained in accordance with the best conservation methods. Planned cutting is practiced. Only the fully mature trees are allowed to be cut, and all their parts that can be used are saved. The waste materials are piled and are burned at times when the ground is wet enough to prevent the fires from spreading. Trees, usually clumps of them along the ridges, are left here and there to start new stands of timber from their seeds. Also, young trees are planted to replace those that are cut. Some trees are removed from places too crowded for their proper growth.

3. Diseases. Trees die of diseases, just like people and other living things. Among the most serious diseases of forest trees are those caused by parasitic fungi.[1] Examples are the rusts that attack evergreen trees over large areas of the West, and the blight that threatens to exterminate the native chestnut trees. Such diseases are most effectively combated

[1]Page 554.

by cutting down and burning damaged trees. Thus the parasites are destroyed before they can find new hosts. Both the United States Forest Service and the Dominion Forest Service (Canada) have numbers of trained scientists who are constantly engaged in studying tree diseases to discover ways of controlling them.

4. Insects. At least two hundred thousand kinds of insects feed upon forest trees and thus injure or kill them. Different kinds feed on the trees as larvae, as adults, or as both. Such insect pests are often brought into the country by accident from another part of the world. In their former habitats they have found their places in the balance of nature.[1] Hence they are not serious pests there. But when introduced here, without their enemies, they multiply rapidly and may cause great damage.

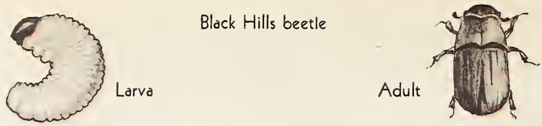
Some of the insect enemies of forests are especially destructive. During the earlier part of this century the larch sawfly spread across Canada, destroying practically all the tamarack trees from the Atlantic Ocean to the Rocky Mountains. The Black Hills beetle is at present the most serious enemy of the pine trees of the central Rocky Mountains region (illustration, p. 112). The larvae of

[1]Page 32.

It is important to attack forest fires before they have had time to spread and get out of control. Hence the fire-fighting forces include "paratroopers," called "smoke-jumpers." They are taken by airplanes to the vicinity of the blaze, where they descend, with their equipment, by parachute. **Topic for Individual Study:** Using flame-throwers and employing other methods of fighting forest fires

United States Forest Service

Holes in tree trunk made by woodpecker searching for larvae



Woodpecker on tree trunk

The larvae of many insects are parasites of various trees. Woodpeckers and many other birds feed on the insects. To which of the principles on page 114 are these facts related? **Community Application of Biology:** Find out whether there are insects that are attacking forest or shade trees in your locality. How are these insects being combated?

the brown-tail and gypsy moths have done millions of dollars' worth of damage to forests and shade trees in New England alone.

An effective way of combating insect enemies of forest trees is to introduce other insects or disease parasites that will attack them. Sometimes individual beetles, moths, or other insects known to be harmful are brought into contact with a disease-producing fungus[1] or other parasite and are then allowed to go free, with the hope that they will spread the disease among others of their kinds.

[1]Page 557.

5. Winds. Strong winds sometimes blow down, break, or otherwise injure vast numbers of trees. In forest areas of the Middle West it is not uncommon to observe the paths of tornadoes marked by fallen, twisted, and broken trees. Perhaps the greatest destruction of forests by wind-storms in recent years was caused by the hurricane that swept across New England and southern Canada in September, 1938, and by the widely distributed gales of June 23, 1944.

Trees that have been blown down should not be left on the ground, especially where they have been destroyed in great numbers.

Those suitable for commercial purposes should be saved. The rest, together with the slashings, should be piled and burned, so that forest fires cannot start in them. Then the bare areas should be replanted with young trees.

6. War. The Canadian and the American forests did not suffer directly from the Second World War, because no battles were fought on this continent. But in Europe, wherever battles were fought in forest areas, the forests were largely destroyed. In the United States and Canada, however, the unusual demands for lumber and wood products to supply war needs greatly reduced the areas of standing timber.

FOREST CONSERVATION · **1. By reforestation.** Most areas from which the trees have been removed by fire or by lumbering interests should be reforested. The United States Forest Service has already replanted several million acres of such land and plans to reforest additional millions of acres every year. Also, the Service is making use, wherever it can, of the preferred practice of leaving mature trees to seed areas naturally.

There are thousands of acres of land in the United States which have been cleared and used for growing food crops, but which have proved of little value for that purpose. This land should be abandoned as farm land and replanted with trees. Increasing areas of it will be.

Reforesting slopes from which the timber has been burned off or logged off is an important method for controlling the erosion of the soil.

2. By establishing wood lots and town forests. About a third of the standing timber in the United States is in wood lots. Most of these are owned by farmers. Several thousand more have been established by reforesting abandoned farm land, and these are owned and maintained by towns. The wood-lot and the town-forest crops include lumber, fence posts, telephone and telegraph poles, firewood, wild fruits and nuts, Christmas trees, and maple sugar. These crops furnish a steady and substantial income.

3. By increasing the uses of soft-woods. There are about a thousand kinds of trees in the forests of the United States and Canada. Of these only about fifty have had wide commercial use. The new urea process of making soft-woods hard will enable practically all the native woods to be used commercially. Furthermore, soft-wood trees that grow rapidly can be grown extensively to take the place, when treated, of the rapidly diminishing numbers of slow-growing hard-woods.

DID CONSERVATION BEGIN IN TIME? · At the time that the colonies at Jamestown and Plymouth were established, there were more than eight hundred million acres of virgin forests in the area that is now the United States. There are still more than six hundred million acres of forest land, but only about one hundred million acres are now covered with virgin growth. About half the total remaining area is covered by second-growth timber, that is, young trees that are growing where the original forests once stood. One hundred and sixty million acres are of no value in their present condition. Only about two hundred fifteen million acres bear trees large enough for lumber.

The situation, however, is not hopeless. There is still enough forest land in the United States to supply our needs if proper conservation is practiced, that is, if wise use is substituted for waste.

CANADIAN FORESTS · The situation of Canada with regard to its forest resources is entirely different from that of the United States. Although Canada is about a fourth

larger than the United States, it has a population only about a twelfth as large. The settling of Canada, therefore, did not result in the destruction of the forests to nearly so great an extent as did the settling of the United States.

Canada still has a belt of timber from six hundred to thirteen hundred miles wide, which stretches from the Atlantic to the Pacific. Much of this timber is owned by the Dominion and provincial governments. Moreover, Canada has come to realize the need for conserving her timber while it is still abundant. As a result, she will be able to maintain her supplies of forest products without great difficulty (illustration, p. 115).

Checking What You Know

BIOLOGICAL FACTS · **Pages 103–108. 1.** American pioneers were (1) purposely wasteful of forest resources; (2) forced by necessity to clear the forests; (3) careful to preserve forests for future generations; (4) wasteful of forest resources for only a short time; (5) disturbed by the waste of forest resources.

2. One of the five endings makes the following an untrue statement. Which one does?

Early lumbering practices (1) increased the danger of forest fires; (2) enabled the logging companies to secure the greatest amount of timber in the shortest time; (3) left the timberland in poor condition for more forest trees to grow; (4) were carried on in ways that would save the young trees; (5) removed from the forest land only the parts of the trees that could be made into lumber, timber, and poles.

3. State five important values of forests and illustrate or explain each.

Pages 108–114. 4. A new forest can be grown to maturity in (1) 5 to 10 years; (2) 10,000 years; (3) 60 to 100 years; (4) 500 to 1000 years; (5) 10 to 25 years.

5. List five kinds of losses, in addition to the loss of lumber, which result from forest fires.

6. Name the six chief enemies of forests and tell how each is harmful.

7. State four methods of forest conservation and illustrate or explain each.

BIOLOGICAL PRINCIPLES · **1.** By their life activities living things affect other living things.

2. By their activities living things bring about changes in the environment, and a changing environment affects living things.

3. Every living thing has its living enemies, which prey upon it or otherwise injure it.

4. Fire, drought, winds, and other non-living enemies affect the welfare of living things.

Applying and Extending What You Know

REVIEW EXERCISE · Complete the chart the beginning of which is shown below. At the left of a page, write the different practices of conservation described on pages 78–99. Write as column headings, in the way shown in the chart, the different advantages of the various methods of conservation. Then check with an **X**, as indicated, each of the advantages brought about by each of the methods of conservation, as stated in the material on those pages. The advantages of the first two methods have been indicated for you.

	Delays Wind Erosion	Delays Water Erosion	Enriches Soil	Adds Water To Soil
Planting cover crops . .	X	X	X	X
Contour plowing		X		X
Terracing				
(Add the others)				

Crown ©, Royal Canadian Air Force

Airplane view of some of Canada's virgin timber · Make several questions which are based on this picture and which relate to conservation. An example would be "What provision for fighting fires in this region has the Canadian government made?"

CONSUMER BIOLOGY · **1.** Why is it good economy for everybody to pay higher taxes in order to provide funds for fighting forest fires?

2. Suppose you wished to buy a wood lot. What information given in this chapter might help you to decide whether it would be a good purchase?

3. Of what value is it to everybody to know that the demands of the Second World War greatly reduced the timber reserves of the United States and Canada?

APPLYING YOUR KNOWLEDGE OF BIOLOGY · **1.** Write as long a list of different uses of wood as you can in three minutes. Which of these uses involves the greatest quantity of lumber?

2. What effects might a forest fire have on the plants and animals that live in streams and rivers which flow through the forest?

3. What evidence can you find in this chapter of man's efforts to control living things for his advantage?

4. Why do you think Canada's forests are not endangered to the same extent as those of the United States?

5. Suppose you became the owner of a large forest and that you decided to become a lumber-

man. What practices would you employ so that you could make a profit from your forest for the rest of your life?

TOPICS FOR INDIVIDUAL STUDY · 1. From an architect or building contractor find out what materials may be used in place of lumber in the construction of homes and buildings. Try to find out what effect the use of these materials in construction will have on the nation's supply of lumber. Also, find out what advantages and disadvantages these materials have as compared with lumber.

2. One way of making our forest resources last longer is the use of substitutes for wood. Plastics are being used to replace wood for many objects. Consult textbooks of chemistry to find out what plastics are and from what substances they are made. Find out, also, as many as you can of the objects that are now made of plastic which were formerly made of wood.

COMMUNITY APPLICATION OF BIOLOGY · Investigating local care of shade trees. Find out from your city or county department of parks or shade-tree commission what is done to protect the shade trees along the streets or along the highways in your vicinity. Find out who is responsible for planting them, protecting them against insects and diseases, pruning them, and removing those that are dying or diseased. How much money is spent for these services? Who pays the cost?

PANEL DISCUSSIONS · A panel discussion is carried on by a panel of about six members and a chairman. All are elected by the class or are appointed by the teacher.

The following directions for the four panel topics given below show how a panel discussion may be carried on: The first two topics are of the type that is controversial; that is, "There are two sides to the question." Both sides should be presented with as many good arguments as possible. In all panel discussions the emphasis should never be upon *who* is right, but always upon *what* is true and *what* is worth considering. In other words, "It is not heat that is wanted, but light." Hence, with topics such as these first two, each member of the panel should be prepared to discuss both sides of the question. The members should talk in any order.

The third and fourth topics are of the type which is not controversial; that is, the question does not lend itself to dispute, controversy, or debate. With topics such as these, the panel members should speak in turn.

In any panel discussion all the members, including the chairman, should prepare, in advance, careful notes to use while taking their parts in the discussion. After the subject has been presented by the panel members, the chairman should draw all the other members of the class into the discussion. Nobody, not even a panel member, should, at any time during the discussion, talk for more than two or three minutes at a time. Moreover, nobody should talk more often than once or twice, because the purpose is to get as many people's views as possible. When the discussion has been completed, the chairman should summarize the arguments on both sides of the question, or the points that have been made.

1. Topic: Every farmer has the right to do as he pleases in the use of the land that he owns.

2. Topic: The Federal or the Dominion government, or the state or provincial governments, should regulate the cutting of all forests.

3. Topic: Conservation is everybody's problem.

In the discussion of Topic 3 each member of the panel should prepare a three-minute talk on one of the following divisions of the topic, assigned to him by the chairman: What can be done by a high-school boy or girl to help conservation? by a newspaper man? by a farmer? by a city dweller? by a lawmaker? by campers? by a high-school science club? by people in other groups?

You may wish to put off this panel discussion until you have finished studying the next chapter, on wild-life conservation.

4. Topic: Values gained from conservation.

6

CONSERVATION OF WILD LIFE

1. To What Extent and Why Are Animal and Plant Populations Decreasing?

Before the white man settled this continent, the wild-animal and wild-plant populations were never seriously threatened. The Indians were not numerous. It has been estimated that their entire numbers in what is now the United States never equaled the present population of Cleveland. They did not destroy much of the forest or use much of the land for crops. Moreover, they did not hunt for recreation, but only to supply such needs as meat for food, skins for robes, shelters, and clothing, and feathers for war bonnets and arrow shafts. They killed many animals and destroyed many plants, of course, but they maintained their place in the community of living things without greatly disturbing the balance of nature.

The early white settlers did not disturb the balance of nature over wide areas much more than the Indians did. Of course they made marked changes in the plant and animal communities around their homes. But, for the most part, they killed only what animals they needed to kill. Hence, over wide areas, the natural increase of the wild creatures was sufficient to make up for such losses of numbers.

As the country became more thickly settled, however, this condition changed. As the human population increased, the animal and plant populations decreased. The white man brought about the rapid destruction of animal life chiefly in two ways: (1) by changing the habitats and (2) by killing for market and recreation.

CHANGING THE ANIMAL HABITATS · Wild animals cannot survive without the right kinds of cover, or shelter. When in the open, they race for cover at the first sign of danger (illustration, p. 118). Cover is provided by plant life. Some animals require forest vegetation. Others find the cover that they need in a tangle of vines or a patch of high grass. Still others conceal themselves among the plants that grow along the margins of streams, ponds, and marshes.

Cover of the right sort makes wild animals relatively safe from predators. Without proper cover, wild animals will not survive, even though there is plenty of food and water near at hand, for they will rarely leave the cover even to seek food and water.

By cutting down the forests and by establishing farms, the settlers destroyed the cover on which countless animals depended. At the same time they destroyed wild flowering plants and other plants which supplied the animals with food. Also, by fencing the land the settlers made the free ranges of some of the widely roaming animals too small for their needs. To illustrate, such animals as the deer, elk, antelope, moose, and bison have proved unable to maintain their numbers when con-

In general, the kinds of wild animals, and of wild plants as well, that have suffered most seriously from the advance of civilization are those that live in forests. From what enemies do you think these deer would seek cover?

fined in relatively small areas. Later, by draining marshes and lakes to secure more agricultural land, people destroyed more millions of wild creatures by destroying their habitats.

It should be kept in mind, however, that most of the destruction of plant and animal life that resulted from the changing of habitats could not have been avoided. Clearing and draining land for farming, developing towns and cities, building highways and railroads, and so on are necessary steps in national progress. The wild things that happened to be living where these changes had to be made were the innocent victims of the march of civilization. We must realize, too, that as the United States and Canada become more thickly settled and completely developed, there will be still fewer wild animals and wild flowers because the areas in which they can exist will necessarily become smaller.

HUNTING · There can be little doubt that the destruction of native habitats by the set-

tlement of the country has been responsible for the disappearance of more wild life than has any other factor. But hunting too has resulted in the destruction of uncounted millions of wild animals.

1. Hunting for market. The trappers and fur-hunters of the Hudson's Bay Company of Canada and the Northwest Fur Company of Montreal played important parts in the exploration of this continent. Men still roam the wildernesses in search of beaver, mink, marten, muskrat, and other animals for the fur trade (illustration, p. 120). At present, too, the demand for furs is increasing, and consequently the numbers of wild fur-bearing animals are continuing to decrease.

Less than a century ago market hunters were making a business of killing and selling pigeons, ducks, and many other game animals for food. Will Cody earned the name of "Buffalo Bill" when he was supplying fresh bison meat to the crews who were building a railroad across the plains to California. Passenger pigeons were slaughtered by millions, packed in barrels, and shipped to markets in Eastern cities, thousands of barrels at a time. The food served in the best hotels of the large frontier cities, a century or less ago, included an astonishing list of large and small game animals. For example, at the Army Reunion Banquet given by the Chicago Chamber of Commerce on December 16, 1868, the following kinds of wild game were served: wild turkey, mallard and teal duck, quail, prairie chicken, grouse, antelope, black-tailed deer, and buffalo (bison).

2. Hunting for pleasure. Hunting for sport, or recreation, is an activity that has developed with civilization. People must have leisure and security in order to hunt merely for the fun of hunting. Primitive man and the Indians, as well as the early pioneers, were too much occupied with the grim struggle for existence to "go hunting" as people do now.

As settlements took the place of the frontiers, game animals in growing numbers became the victims of their chief predator, man. In the early days there were no laws to protect wild life. Hence the slaughter of game animals was so great that it can scarcely be imagined.

VANISHING WILD LIFE · **Animals.** Passenger pigeons were once so numerous as to "darken the skies" in their migration. The last of these birds died in 1914. The last of the heath hens, once abundant in many localities, died in 1932. The Labrador duck, the Eskimo curlew, the Carolina parakeet, the Maine giant mink, and other birds and mammals have disappeared from this continent. It is estimated that for every bison now alive there were once ten thousand (illustration, p. 33). Many other wild animals are in danger of becoming extinct (illustration, p. 121). There can be little doubt, moreover, that hunters are today the gravest threat to the game animals that still remain. As one example, in a single recent year more than six hundred thousand deer and nearly thirty-five thousand elk were killed by licensed hunters.

The sober fact is that the present wild-animal population of the United States is only about 2 per cent of that which inhabited the same area in colonial times. It is neither desirable nor possible to restore this population. We should, however, conserve all we can of what remains.

Plants. The case of the wild flowering plants is similar to that of the wild animals. Many kinds have already become extinct in localities where they were once plentiful, and the decrease in their numbers is certain to continue. Every effort should be made to

Fur-bearing animals of North America · Can you name other animals besides these that are hunted for their furs?

These and other native wild animals are in danger of becoming extinct. **Bulletin-Board Display:** Find out from your state or provincial department of conservation what wild animals, once plentiful in your locality, are now extinct or nearly so. Secure or draw pictures of them for a bulletin-board display

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Bulletin-Board Display: Draw a cartoon appropriate to some aspect of wild-life conservation

save the remaining ones. Even though some kinds are still so plentiful that they are not likely to become extinct through being picked, it is too difficult to remember what these kinds are. Hence it is better not to pick any, because of the danger of exterminating kinds that are already scarce (illustrations on this page and page 123).

"INTER-LOCKING" CONSERVATION · An example that shows how one kind of conservation often is related to another is furnished by the use of club mosses[1] as Christmas greens. These beautiful plants are known in different localities as ground pine, running cedar, and running cypress. Their underground stems[2] run along just beneath the surface of the soil. Hence when these plants are gathered, their stems and roots are torn out of the ground, and thus the soil is exposed to rapid erosion.

In some localities club mosses are the only covering over the thin soil of woods. Gathering them, therefore, soon results in the destruction of the soil. The destruction of the soil leads in time to the destruction of the woods and of the wild life in them.

The holly which is grown as a crop, and mistletoe, which is a parasite on valuable trees, provide Christmas greens that can be used without resulting harm.

2. What Conditions Make the Conservation of Desirable Wild-Animal Life Difficult?

The problems of wild-life conservation would be much simpler if all the wild creatures were either definitely friends or definitely foes of man. But they are not. A few are always classed as friends. Perhaps still fewer are always considered to be enemies. Nearly all of them have habits of life that make them in some respects useful and in others harmful to man in his struggle for existence.

In the group of constant friends of man are a considerable number of insect-eating birds.[3] In the group of man's constant enemies are several rodents, or gnawing mammals.[4] Of

[1]Page 560.
[2]Page 430.
[3]Page 129.
[4]Pages 123–124.

these the rat is the worst. There seems little, if any, doubt that man would be better off if this animal, and probably some of its relatives, could be exterminated. Here are some reasons why:

RODENT ENEMIES · Rats live almost everywhere that people live. They have accompanied man to all parts of the world in ships. Formerly they lived chiefly in cities. Recently, however, as building construction and sanitation[1] have been improved in cities, most of the rats have migrated to the farms. Rats are so successful in the struggle for survival that their present population is believed to be double the human population.

It is estimated that rats eat and otherwise destroy as much food yearly as two hundred thousand farmers can produce (illustration, p. 124). They will eat practically anything that people eat. Furthermore, they destroy more food than they consume, and sometimes they do it for reasons that we cannot understand. For example, a farmer, after harvesting his potatoes, failed to store several bushels safely for the night. The next morning he found that rats had destroyed all those potatoes by chipping them into little slices with their teeth.

Rats kill more poultry than do foxes, skunks, weasels, hawks, minks, and owls together. Also, they eat eggs. They do further damage by gnawing buildings, furniture, books, and many other kinds of property.

From all these facts it is not surprising that the yearly damage done by rats in the country is said to amount to a dollar per rat, and by rats in the city to two dollars per rat.

[1]*Sanitation* (săn ĭ tā′shŭn): the science of improving health by improving living conditions.

Wild flowers are loveliest where they are growing. How many arguments can you suggest that might be used to discourage the picking of wild flowers?

The Wild Flower Preservation Society

United States Fish and Wildlife Service

The benefits we derive from insect-eating birds are indirect, while most of the damage done by rats is direct. Explain. The Laysan[1] rail, a small, snipe-like wading bird found only on Laysan island in the Hawaiian Islands and on Midway, became extinct in 1946. These birds were exterminated by rats. To which of the principles on page 142 do these facts most closely relate?

Other rodents, such as mice, rabbits, squirrels, and gophers, compete with man and his domestic animals for the available food supply, just as rats do. They eat and destroy enormous quantities of crops and stored foods. In some of the Western ranges rodents destroy as much forage as the range cattle eat.

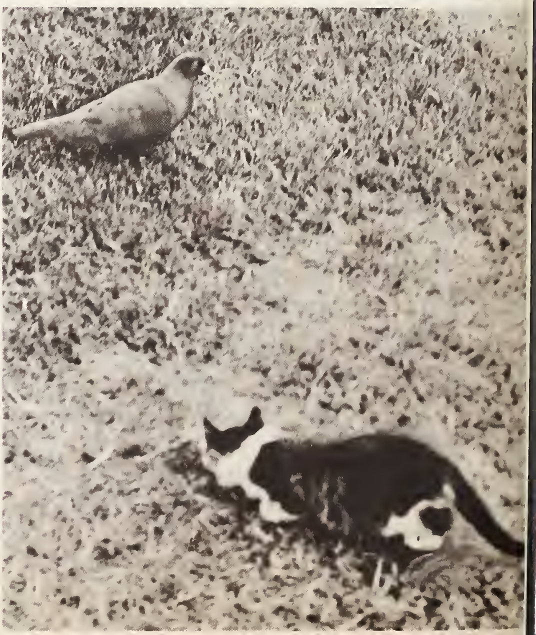
Marmots (woodchucks) and other burrowing rodents sometimes damage irrigation dams. Squirrels eat birds' eggs and probably young birds. Rabbits injure orchard trees, shrubs, and forest trees by gnawing their bark. Rabbits and some kinds of squirrels, however, are used for food, and their furs are of considerable value.

Cats are good allies of man in killing mice, rabbits, squirrels, and gophers, but they are much less valuable as rat-catchers than terrier dogs, or gopher snakes and some other common snakes. It is doubtful, moreover, if cats actually destroy enough rodent pests to make up for the harm that they do in killing birds (illustration below).

KILLING ANIMALS THAT ARE SUPPOSED TO BE HARMFUL · We are likely to be more strongly impressed by the harm that animals do than by the good. Thus we are likely to treat as enemies many animals whose life habits really make our survival easier. For example, hawks of all kinds have often been vigorously hunted because those of some

The pigeon is too large for the kitten to capture; yet the latter is stalking it nevertheless. **Topic for Individual Study:** The work of John James Audubon

E. H. Smith, from *Nature Magazine*



[1]*Laysan* (lä′ē sän).

kinds catch an occasional young chicken (illustration on this page). But all the larger species of hawks kill countless rodents, and the smaller ones feed chiefly on insects.

Many farmers have shot as many as they could of the robins and other birds that fed on their cherries and other small fruits. Later, others of their crops have been destroyed by the insects which these birds would have eaten.

We must not think, however, that because animals more useful than harmful have often been destroyed, no predators should be destroyed. The United States Fish and Wildlife Service makes constant studies to determine whether various kinds of wild animals are of more value than harm. There can be no doubt that the harm done by many kinds of rodents greatly out-weighs the good. Consequently the Service carries on or directs the destruction of these kinds on millions of acres of farm and ranch land every year.

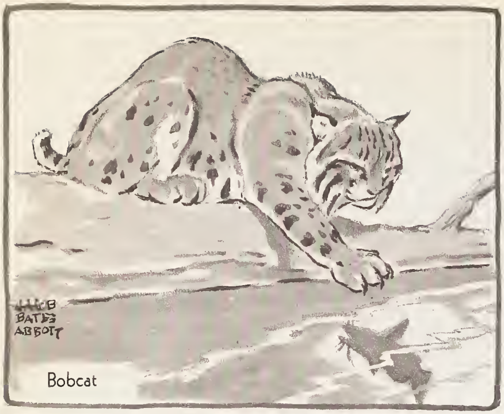
Sometimes the Service decides from these studies that certain predators should not be killed generally, but only in certain localities. For example, it found that coyotes were killing an average of eighteen chickens per day on one Texas farm, and that they were killing about 50 per cent of all the turkeys in one Texas county. Also, it discovered, in one California county, that turkeys could not be raised profitably there because of coyotes. The Service sent its own hunters to reduce the coyote populations in these Texas and California localities. It did so, however, only after careful study, because in many other areas coyotes are such valuable allies of farmers and ranchers in killing rodents that they more than make up for the harm they do in killing poultry and even sheep.

There are a number of instances in which the Service has had to reduce the numbers of wolves, bobcats, lynxes, mountain lions, and stock-killing bears in certain localities. Such destruction of animal life, however, is never carried on except where it has been found to be necessary and has been approved by a state or a provincial department of conservation, by the Fish and Wildlife Service, or by some other government agency.

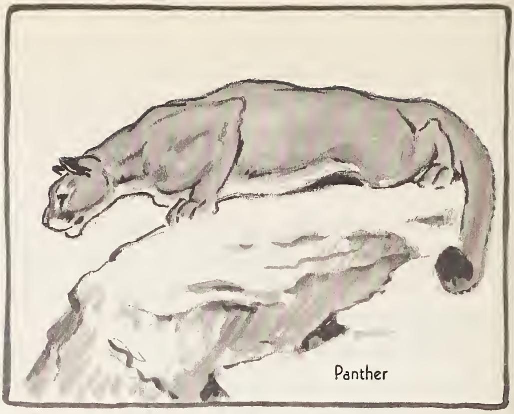
Lincoln, from United States Fish and Wildlife Service

This predator, the sparrow hawk, is one of the most valuable of the persecuted animals. Predators kill more sick and weak animals than strong and healthy ones. To which principle (p. 142) does this fact relate?

KILLING ONE KIND TO SAVE ANOTHER • There have been many instances in which certain animals have been killed in great numbers because they preyed upon other animals which the government or hunters wanted to conserve. Later, however, the results of such destruction have often proved serious in unexpected ways. For example, some years



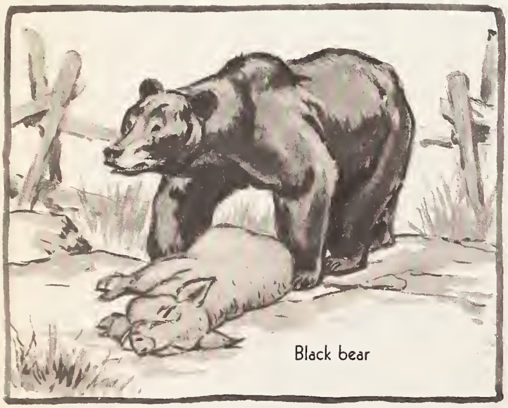
Bobcat



Panther

Red fox

Weasel



Black bear

Skunk

What predatory mammals live in your locality? What other predators than the ones shown here can you name? To which order of mammals[1] do you think the predators belong (illustration, p. 549)?

[1]Pages 547–550.

ago the United States government hired hunters to kill bobcats and panthers in some of the government forest lands because these animals were killing so many deer (illustration, p. 126). After enough of these enemies had been destroyed, the deer multiplied so fast that they soon became too numerous for the available food in the forests. They then raided the neighboring farmers' crops.

Bounties, in the form of stated sums of money, have often been paid by states and counties for the killing of hawks, eagles, wolves, foxes, and many other predators believed to be killing too many game animals. In practically every case it was found later that the killing of the predators permitted some other, probably more destructive enemies to increase to a point where they did more harm than the animals that people had been encouraged to kill.

Mistakes such as the one described on the preceding pages are costly because they disturb the balance of nature. They will continue to be made, however, until biologists learn enough about the life habits of the various animals so that we can be sure (1) which are useful so that they deserve protection and (2) which are so harmful that they should be destroyed.

HUNTING BY AIRPLANE · Airplanes bring practically all "game country" within reach of hunters. Recently, for example, hunters have flown to parts of the Alaskan forests never before visited. Thus the last safe refuge of many large game animals is gone.

Hunting coyotes by airplanes has recently become a "sport" in some of the Western states (illustration, p. 128). These animals might be able to escape from or to avoid hunters who were on foot or even in automobiles. They have, however, a far smaller chance of escaping those in airplanes.

The commercial hunting of whales by airplane is a recent development. Planes cruise over the ocean to locate the schools of whales and to direct the whaling boats to them.

It is predicted that the use of airplanes for reaching the habitats of game animals all over the world will raise new problems of conservation in the future.

CONSERVATION, A STRUGGLE · The preceding paragraphs indicate that the conservation of wild animals, like that of other natural resources, is a constant struggle between those who want to protect them and those who would allow them to be destroyed. This latter group includes (1) those who do not realize that there is grave danger of exterminating the wild creatures; (2) those who are indifferent to their fate; (3) those who enjoy hunting them; and (4) those who profit by their destruction (illustration, p. 129).

SHALL HUNTING BE ALLOWED? · It is difficult to decide to what extent hunting should be allowed. Many people find it hard to understand how others can get pleasure from hunting. They think of it as a cruel practice that cannot help bringing terrible suffering to many helpless creatures. Yet, if no hunting were permitted, many kinds of wild animals would become too numerous for man's welfare. They would do damage in many ways if not held in check. For example, during 1944 the deer in one state forest multiplied greatly. At the same time the plant life on which these animals normally feed became scanty because of drought. The state rangers knew that during the next fall and winter the deer would be forced to browse on the trees to keep from starving. They knew, also, that the deer would thus do great damage to the forest, but that they still would not be able to get enough food to pre-

vent most of them from starving and the survivors from being greatly weakened.

To solve this problem, the department of conservation of the state petitioned the legislature to pass a special law for that one year. This law would allow hunters to kill not only more male deer, or bucks, than in an ordinary hunting season, but also a certain number of females, or does,[1] which are usually protected. By this law the department of conservation hoped to save both the herd and the forest.

The law was passed as a conservation measure. Later it was found to have accomplished its purpose of saving both the deer herd and the forest.

The whole problem of conserving our wild animals and yet keeping their numbers within proper bounds can be solved only when more is known about them and their ways of life.

3. How May Wild Life Be Conserved?

If you were taking a vacation in one of the localities where game animals live, you would probably sooner or later meet a game warden. It is the game warden's duty to see that the laws protecting wild life are enforced.

METHODS OF WILD-LIFE CONSERVATION · 1. **Protecting by law.** Laws have been passed for the protection of game animals in every state of the United States and every province of Canada (illustration, p. 129). These laws vary widely in different localities with respect both to the animals protected and to the lengths of their open seasons. For most game animals the "closed seasons"—that is, the times during which they must not be hunted—cover the times of year when they are raising their young or are migrating, or are doing both. For some animals, such as bison and elk, which are almost extinct, constant protection is provided.

In most localities, as has been indicated, hunters may shoot only the males of certain kinds—for example, deer and Chinese pheasants. Moreover, the number of deer, ducks, or other kind of game animal which any individual hunter is allowed to "bag" during the open season is limited to one or a few (illustration, p. 130).

There are some national and international laws for protecting wild life. The Lacey Act, passed by Congress in 1900, forbids the shipping of game which has been killed out of season or in any other way that is not legal. The McLean Migratory-Bird Treaty, between the United States and Great Britain, was signed in 1916, to protect birds migrating between the United States and Canada.

1. Closed season
2. Restricted season
3. Hunting for sale

4 Can only kill male
5. Bag limits
6 Limit of size

[1] *Doe* (dō).

Two coyote puppies coming out of their den in Sequoia National Park · What domestic mammal do you think they most closely resemble?

National Park Service

National Parks Bureau, Canada

Sea lions on a rock in the ocean · These are not game animals; yet so many are being killed for the manufacture of canned dog food that they are in danger of becoming extinct. They are protected on these rocks by the Canadian government. Why do you suppose they are? What is a game animal?

A similar treaty was signed between the United States and Mexico in 1936. These treaties are planned to protect all migratory birds the life habits of which are believed to be either helpful to man or at least not harmful to him. They provide closed seasons for migratory game birds, such as geese, ducks, rails, swans, plovers, snipes, woodcocks, curlews, wild pigeons, and doves. They provide a permanent closed season for non-game, insect-eating birds, such as catbirds, robins, meadow larks, woodpeckers, wrens, and warblers, and for other non-game birds, such as gulls, herons, petrels, and bitterns. These treaties further forbid the taking of the eggs or the nests of these birds except for scientific purposes or for propagation (producing young). The sale and shipment of birds protected under these treaties are likewise prohibited.

How effective is such protection? Under legal protection some game animals have become plentiful in certain sections. For example, some years ago, in Oregon, Chinese

Ripley, from United States Fish and Wildlife Service

One of the annual duck stamps · What questions does "annual duck stamp" raise in your mind? Your local postmaster can probably answer most of them

pheasants, after a continuous closed season of five years, became so numerous as to be a pest to farmers because of the grain they ate. Deer have multiplied so greatly in parts of Pennsylvania, New York, and some other states that they are in no immediate danger of becoming extinct, provided that the present protection is continued.

Protecting animals by laws, however, is a less effective method of conservation than it should be. In some cases the laws are not well enforced. Also, there are people who try to secure the passage of game laws or to secure changes in such laws so that they can hunt the protected animals more freely, or so that they can profit by having them hunted. Two incidents of many that might be described will illustrate this last statement:

Some years ago it became certain that wild ducks of several species had almost become extinct. Congress therefore passed a law shortening the open season of these ducks to one month per year for a three-year period. Because of this added protection, the ducks increased in numbers. As soon as this increase had become clearly evident, Congress was

influenced to extend the open season first to forty-five days and then to two months.

A few years ago the Emergency Conservation Committee wrote the newly elected governor of one of the states, urging him to appoint a conservation commissioner to protect wild life. The governor appointed a man who made part of his income from the sale of guns and ammunition. This man immediately expressed himself in favor of having the state parks, which were wild-life sanctuaries, opened for hunting.

A pleasant contrast to the attitude of this commissioner was furnished during the Second World War by Admiral Nimitz. He did his utmost to protect the wild life on the Pacific islands which our armed forces captured from the Japanese. (JACK MINER)

2. Establishing sanctuaries and refuges. Wild-life sanctuaries and game refuges have been established in increasing numbers by private individuals, by states and provinces, and by the United States and Canadian governments (illustration below). In such areas wild animals are protected from hunters and all others who might threaten their safety. Wild flowers are likewise protected. Such refuges, besides offering protection to wild life, provide attractive public-recreation areas.

[illegible] SOCIETY

During the Second World War our armed forces in the Aleutians discovered small colonies of sea otters on two of the islands (illustration, p. 120). So few of these valuable fur animals remain that the United States government at once made these islands refuges for sea otters and sent a corps of wardens to protect them from hunters. Also, it is keeping the location of the two islands secret.

Now and then some kinds of animals become too numerous in the public sanctua-

Canada geese on a national wild-life refuge in Michigan · Here several hundred of these birds spend every winter, safe from all hunting except "hunting with a camera." The natural increase of game animals is commonly called a "game crop." Can you explain what is meant by this term?

Bert Stoll, *Bay City Times*

Soil Conservation Service

Providing suitable natural habitats for wild animals is the best method of increasing their numbers. Fence rows, such as the one shown here, and hedges provide both cover and lanes of travel for small mammals and insect-eating birds. Using hedges instead of fences also aids in reducing erosion, especially if the hedges are planted on contour lines. Explain

ries. In such cases the government either transfers the surplus to other sanctuaries or occasionally permits the animals to be hunted until their numbers have been sufficiently reduced.

3. **Restoring former habitats.** The draining of lakes and marshes to provide more farm land, during the period following the First World War, uncovered much land that was later found not to be suitable for crops. Recently, therefore, considerable areas of such land have been restored to lakes and marshes. As a result, there has been a great increase in the numbers of wild fowl of many kinds and of such animals as muskrats and beavers (illustration, p. 120).

In some farming communities land which has been so badly eroded that it cannot be restored to crop production is being planted with vegetation so that it will provide animal habitats. Reforestation, moreover, wherever it is being carried on, is likewise providing habitats in which wild life may multiply greatly.

4. **Improving living conditions.** *a. By providing cover.* Birds and other small wild animals can be encouraged to live around our homes if proper cover and food are pro-

vided. Such cover may consist of trees and shrubs around our houses, and wild vegetation along fences, along the edges of fields (illustration, p. 132), in gullies that are planted to prevent further erosion, and along the banks of streams and ponds.

The best cover is that which is distributed so that the wild things can go from one patch of vegetation to another without having to emerge into the open. This fact was learned long ago in England and on the continent of Europe. There hedges are used for farm boundaries, and strips of plant life are left along the margins of fields. These stretch like a net over the country and thus permit animals to travel to food and water while concealed. The shelter-belt plantings in the Dust Bowl are providing a network of cover which is proving of great value to the farmers by attracting insect-eating birds.

b. By supplying food. The cover which is provided should contain food plants for the animals. Acorns, which are the seeds of oak trees, are eaten by bears, raccoons, turkeys, pigeons, doves, grouse, quail, many kinds of ducks, and a host of other animals. Berries furnish both food and water to quail and some other animals. The seeds of grasses and other plants that make up the cover also serve as food for many kinds of birds. Some farmers do not harvest the two or three rows of corn nearest the edges of their fields in order to furnish cover and winter food for wild animals.

5. Raising fur and game animals. Commercial trapping has so greatly reduced the numbers of fur-bearing animals that trapping in many parts of the country has ceased to be profitable. Consequently, within fairly recent years, fur farming has become established as an industry. There are now many thousands of fur farms in the United States and Canada. On these farms breeders raise foxes, muskrats, skunks, minks, raccoons, and otters, and even chinchillas (illustration above). These animals are well fed and cared for. They are protected from their enemies, and, at the time when their fur is in best condition, are killed without pain.

Domestic hens have long been used to hatch the eggs and raise broods of wild ducks, pheasants, and quail. Recently the raising of game birds has developed into a substantial industry in the United States and Canada In a single year more than twenty-five hundred wild geese and nearly fifty thousand wild ducks were raised in captivity in the United States.

Science Service

A chinchilla is a rodent about the size of a young rabbit. It is the most valuable fur animal. It is indigenous[1] (native) to Peru and Chile, where it has almost been exterminated. A chinchilla coat may cost eighty thousand dollars. How are these facts related to the illustration on page 2?

[1]*Indigenous* (ĭn dĭj'ē nŭs).

4. What Are Some Effective Ways of Conserving the Fish Population?

About forty years ago a railroad was built along the bank of a small mountain stream in the Far West. This stream ran through virgin forests and was full of trout, and, in the fall, of salmon also. The men working on the railroad-construction crews spent much of their free time in fishing. Also, they spread nets across the deep holes. To secure fish even more easily, they sometimes exploded dynamite in the pools, thus killing all the fish there, both large and small. Then, as the dead fish floated down into shallow water, the men picked up those they wanted and let the rest go to waste.

The completion of the railroad enabled crowds of fishermen to reach every part of the river. Soon, therefore, practically all the remaining fish of legal size that had survived the fishing and dynamiting while the railroad was being built were caught. Thus another fine trout stream was added to the long list of those that had become "fished out."

For several years before the attack on Pearl Harbor, the Japanese sent "floating canneries" as close to the Alaskan coast as they were permitted by treaty to go, just when the salmon were returning to the Alaskan rivers to spawn. The Japanese caught and canned so many of the salmon that the Alaskan fishing industry was threatened. Even more serious was the danger that the Alaskan salmon would be exterminated because not enough to maintain their numbers were able to reach the spawning grounds.

MAN AS AN ENEMY OF FISH · By fishing for recreation or for commercial purposes people have caught and are continuing to catch millions of fish of many kinds (illustration, p. 12). Also, by other activities people destroy millions more without intending to do so: (1) By emptying wastes into rives and lakes they cause the water to become unfit for fish. Some of these wastes—for example, oil from oil-burning steamers and chemicals from various manufacturing plants—poison the fish. Some effects of other wastes have already been described.[1] (2) By constructing power and irrigation projects, people sometimes change the rivers so greatly that the fish are no longer able to live in parts of them or to reach head-waters, where they spawn (lay their eggs).

ENEMIES OF FISH BESIDES MAN · Man is the chief enemy of fish, just as he is the chief enemy of many other kinds of wild life. Fish have many other enemies, however. These include parasites and animal predators. Among the parasites are those, such as bacteria and other fungi,[2] that cause diseases, and those, such as protozoans[3] and flatworms,[4] that kill their hosts by consuming them. You may have observed on goldfish white spots caused by a fungus parasite.

Among the predators are bears, otters, minks, and other wild animals, as well as kingfishers and many kinds of ducks and other birds. The common water snake is said to kill more trout than any other predator except man. Turtles also kill enormous numbers of fish.

METHODS OF FISH CONSERVATION · Conservation agencies are using, with considerable success, several means of maintaining and increasing the fish population:

[1]Page 29. [2]Page 557. [3]Page 513. [4]Page 521.

1. **Providing suitable habitats.** The United States Fish and Wildlife Service and state departments of conservation are improving many rivers for fish (1) by making the spawning grounds larger; (2) by increasing the number and extent of riffles, that is, stretches of shallow water where the current is swift and "broken"; (3) by increasing the areas suitable to the growth of plants that serve as fish food; (4) by deepening and widening the pools; (5) by putting piles of brush in parts of the streams and providing other suitable cover; (6) by removing sources of pollution[1] of the water; and (7) by constructing fish ladders (illustration below).

2. **Protecting by laws.** Many laws have been passed in the states and provinces for the protection of fish. These laws have stopped water pollution in some localities. They state the numbers and sizes of fishes, of the various kinds, that can be caught. They regulate the sizes of nets that can be used.

[1] *Pollute* (pŏ lūt′): to contaminate (kŏn tăm′ĭ nāt), that is, to make unclean or foul. *Pollution* (pŏ lū′shŭn): the act of polluting or state of being polluted. Often *pollute* and *contaminate* mean "to make dangerous with disease germs."

DEF

A fish ladder at Bonneville Dam in Oregon · A fish ladder is a series of pools, like steps, so spaced that fish can easily leap from each into the next higher one. Thus fish ladders provide an easy way for the fish to go around falls and dams too high for them to leap over, on their migrations to the spawning grounds. Why is this fish ladder of importance to you if you live in a great city, on a farm, or anywhere else?

United States Fish and Wildlife Service

They state the closed seasons for many kinds of fish.

Similar laws protect some kinds of shell-fish (mollusks and crustaceans[1]) in certain localities. For example, the great gweduc clams of Puget Sound have been saved from extinction by closed seasons, as have clams, oysters, and scallops of other areas.

3. **Restoring fish populations.** Fish hatcheries are maintained in many places by the national government and by state and provincial governments. In these hatcheries food fish are raised by the millions for stocking streams and ponds. The fresh-water varieties include salmon, trout of several kinds, shad, whitefish, catfish, sunfish, bass, and pike. The salt-water varieties include haddock, flounder, and cod.

Female fish lay their eggs, called roe, in long rolls. Each roll contains thousands of eggs. The eggs will not hatch unless the male fish fertilize them. The males swim over the roe and deposit in the water millions of sex cells called sperms. The sperms are microscopic and look somewhat like tadpoles with long, hair-like tails. They swim about in all directions vigorously. When one happens to reach an egg, it penetrates it and fertilizes it, thus producing an embryo**[2] fish.

To obtain the eggs needed for propagating fish in hatcheries, conservation agents secure the males and females at spawning time. The ripe eggs are gently squeezed from the female fish, and the sperm cells are removed in the same way from the males. The eggs are put into pans of water, where they are fertilized by the sperm cells which are poured over them. The fertilized eggs are then put into shallow trays, over which water is kept constantly flowing.

After the eggs have hatched, the young fish are kept and protected through their earlier stages of development, when they would be captured most easily by snakes, larger fish, and other enemies. Then they are transferred to their new homes.

Several kinds of shell-fish are now propagated in hatcheries. These include oysters, lobsters, and the species of fresh-water clams from the shells of which pearl buttons are made. An area has recently been set aside in Virginia as a sanctuary for spawning crabs.

4. **Planting in new localities.** Like all other living things, fish and shell-fish are able to live in other habitats besides those which they happen to populate. Knowing this fact, conservation agencies are constantly trying to establish desirable kinds in new habitats. Many of these experiments have proved successful. For example, the large Eastern oyster has been planted successfully in a number of areas along the Pacific coast. The large trout of the Great Lakes has been established in Lake Tahoe, California (illustration, p. 137). Some years ago rainbow-trout eggs were brought from the United States to Lake Titicaca (between Bolivia and Peru). Now the largest trout known, some of which are more than three feet long, are plentiful in the lake. Bass, crappies, and other popular food fishes, raised in hatcheries, have been transplanted to many new localities.

Through experimenting and observing it has been learned that it is possible to stock too heavily. Planting too many fish sometimes results (1) in the starvation of many, (2) in the failure of all to grow as fast or as large as they should, and (3) in epidemics of disease due to over-population.

[1]Pages 524 and 530.

[2]*Embryo* (ĕm′brĭ ō): a young animal or plant in its earliest stages of development. An embryo animal is the young animal before it is born or before it is hatched from the egg. An embryo plant is the young plant within the seed or the spore (reproductive cell).

Oregon State Highway Commission

The numerous trout in Crater Lake, Oregon, are the descendants of minnows that, many years ago, were carried there in canvas buckets on pack horses over the mountain trails. How do you account for the fact that there were no fish in this lake before some were "planted" in it?

N. 8 *An experiment in conservation.* In order to solve a problem caused by the recent building of great dams, the experiment was tried of transplanting mature salmon instead of young ones raised in hatcheries. This experiment was based on a knowledge of the life habits of salmon. After young salmon reach a certain stage in their development, they migrate to the ocean. There they remain for several years, until they become ready to reproduce. Then, in late summer and fall, they return in great migrations called "runs." Each salmon will go only to the stream where it began life. The female lays its eggs and the male fertilizes them only in the upper reaches of that one stream.

The completion[1] of the Shasta and Grand Coulee dams shut off the spawning grounds in the upper Sacramento and upper Columbia rivers respectively. These dams are too high to permit the construction of fish ladders which would enable the migrating salmon to go around them. The salmon that migrated to the ocean from either of these rivers before the dam was built would neither return to any other stream nor spawn anywhere in the lower part of the river. Instead they would remain in the water below the dam until they died, or they would be killed in trying to get through the

[1] "This Book and You," p. xiii.

spill-ways which carry off the superfluous water from above the dam.

The United States Fish and Wildlife Service tried this experiment: During the annual salmon run they trapped the salmon below each of the great dams. They transported the fish to hatcheries, in specially constructed, thousand-gallon tank trucks. There the eggs from the females were fertilized with sperms from the males. When the young fish that hatched from these eggs became large enough, they were planted in the streams that flow into the Sacramento and Columbia rivers below the great dams.

The experiment proved successful. Five years after the first "crop" of young salmon had been "planted" in these streams, they returned as adults to spawn in the streams where they had been released.

This change, however, is raising grave problems. Adding great numbers of salmon that would ordinarily spawn in the upper branches to those that would spawn in the lower branches of the two rivers will probably render the food supply there insufficient. It is likely, moreover, to result in widespread death from diseases, since disease epidemics commonly follow over-population.[1] Also, the descendants of the fish which for centuries have developed during early life in the upper branches of the Sacramento and Columbia rivers may not be adapted to reproducing continuously in the lower branches.

All the results of this experiment will not be known for many years.

5. Establishing private fish-ponds. On an increasing number of farms artificial ponds are being made by directing run-off water into basins which have been prepared in gullies or other depressions. The banks and margins of these ponds are planted with cover suitable for various kinds of wild life. The ponds are fenced to keep out cattle and other live-stock, which might destroy the cover and foul the water. Then the ponds are stocked with fish of suitable kinds (illustrations, pp. 92 and 139).

N.B. These ponds serve many purposes: They help to reduce erosion, to prevent floods, and to raise the water table by retaining run-off water and allowing it to sink into the ground. They provide a store of water which can be used for fighting fire and, in some cases, for irrigating farm land. They provide homes for wild life, especially ducks and other water birds. They provide opportunities for outdoor recreation, such as fishing, swimming, and boating. They preserve natural beauty. They supply already nearly two million "pan fish" yearly, to supplement the meat supply.

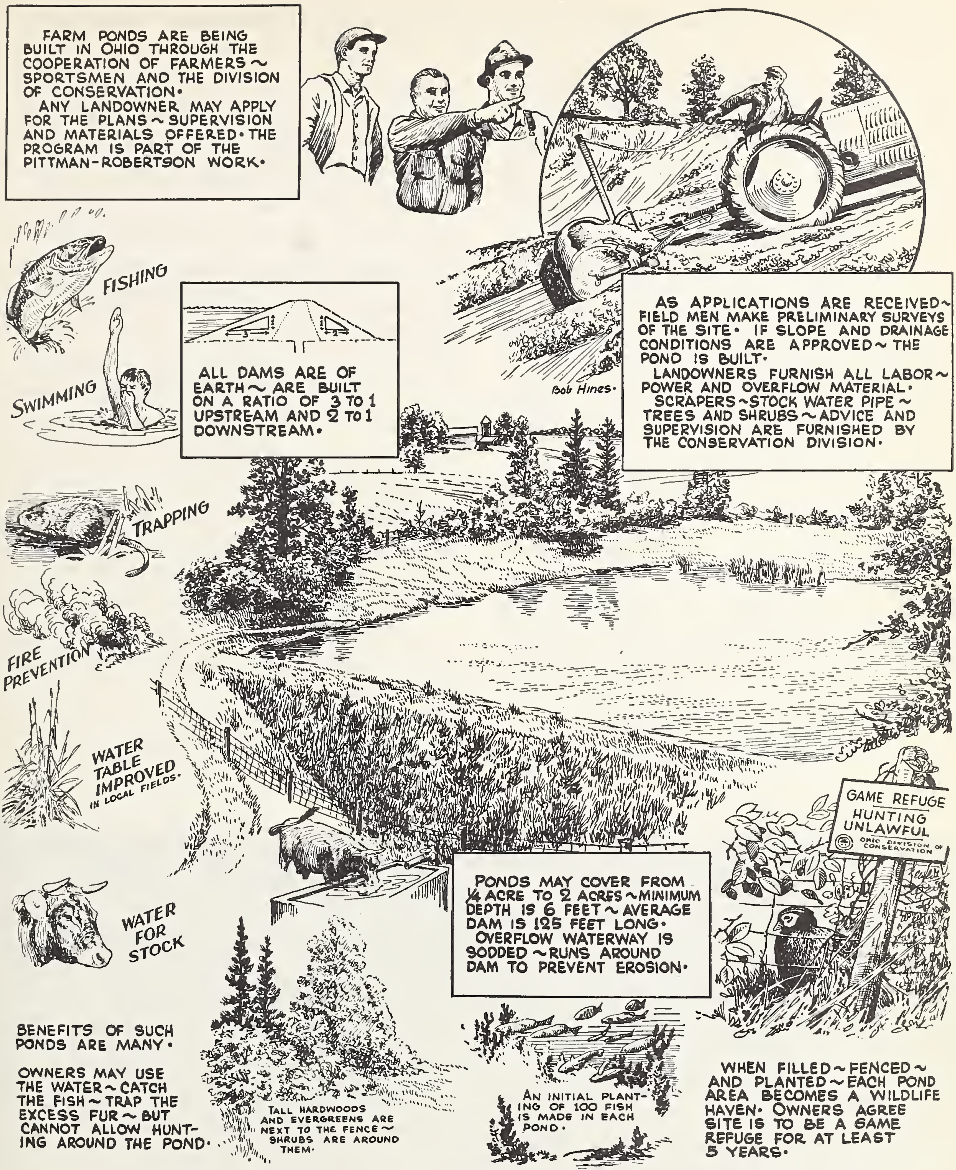
In 1943 more than three million fish, mostly bass and sunfish raised in government hatcheries, were transplanted to farm ponds and other ponds in thirty-nine states.[2] Recent experiments by the United States Fish and Wildlife Service have proved successful in stocking Southern farm ponds with mullet, an ocean food fish.

The mullet become adapted to living in fresh water by being put, first, into ponds of ocean water. Then fresh water is added at intervals to the salt water. Finally the fish become used to water with so little salt in it that they can be transferred to fresh water without harm. Not many kinds of ocean fish could thus become adapted to living in fresh water.

In many parts of the country you will find private ponds or screened-off parts of streams where you may fish by paying a fee. These commercial "fishing holes" are kept well stocked with fish and are carefully maintained so that you will be sure to catch the number permitted. The surplus fish raised in these ponds are sold to near-by hotels and resorts.

[1]Page 32.

[2]Page 142, No. 5.



Robert Hines, from *Ohio Conservation Bulletin*

Make up several questions that can be answered from a study of this illustration and the text material. An example of such questions is this: "Why are stock not allowed to drink right out of the pond?"

5. How Is Conservation Practiced in the National Parks?

The first national park in the United States was Yellowstone National Park. It was established in 1872. Canada's first, Banff National Park, was established in 1885. The United States now has twenty-eight national parks, and Canada twenty-six. Each nation has others projected. There are good prospects, moreover, that another international park similar to the Waterton-Glacier International Peace Park, which includes parts of Montana and Alberta, will be established by the United States and Mexico. This park will include Big Bend National Park in Texas and a similar park to be established adjoining it across the Rio Grande.

WILD LIFE IN THE PARKS · Within the national parks all plants and animals are protected (illustration below). The completeness of this protection is indicated by this statement, which a government ranger made to a visitor in Grand Canyon National Park: "The person who kills a rattlesnake, unless he can actually prove that he killed it to save somebody from being bitten, is as subject to punishment as the one who shoots a deer." The purpose of such protection is to maintain the balance of nature which prevails when man does not interfere.

No hunting is permitted, except the occasional, carefully controlled hunting of animals that have become too numerous for the resources of the habitat. It is then permitted only when the surplus animals are not needed for stocking other wild-life preserves. "Hunting with a camera" is encouraged. Fishing is allowed under careful control of the sizes and numbers of fish caught.

The parks are left in as nearly their natural state as possible. Only enough of the brush

A successful "camera shot" at night in a national park · How do you account for the fact that these five raccoons and the skunk are so tame?

Sequoia National Park

and growth in the forests is removed to prevent forest fires. Nature trails for hikers and horse-back riders lead to all the points of special interest and beauty.

THE SPIRIT OF THE PARKS · These quotations from one of the national-parks bulletins show the purpose and spirit of the parks and how the cause of conservation is advanced by the National Parks Service:

Many of the parks contain noble forests, but the trees are preserved for their beauty and never considered as lumber. It is a strange fact, but often the trees that add most to the beauty of the landscape in reality have no commercial value.

There are many wild animals, but they never are considered from the standpoint of food supply. . . . Many an erstwhile hunter, having laid down his gun for a camera while in a park, never cares to shoulder a gun again. The gentle-eyed deer becomes a friend, not an intended victim. The lesson of the national parks is that wild animals greatly fear man only when man is cruel and murderous. Another lesson from national parks' experience is that practically no wild animal will injure human beings except in self-defense.

Checking What You Know

DO

BIOLOGICAL FACTS · (*Do not write in this book.*) **Pages 117–122. 1.** Some kinds of *wild animals* cannot survive if their cover is completely destroyed.

2. Suitable cover provides wild animals with shelter, --?--, and protection against --?--.

3. Many kinds of game animals have disappeared entirely from their former habitats as a result of hunting for --?-- and hunting for --?--.

4. State three examples of wild life that has been exterminated or at least greatly reduced in numbers because of the destruction of their natural habitats.

Pages 122–128. 5. A rodent that probably should be exterminated, if possible, is the --?--.

6. When a harmful predator is vigorously hunted, its destruction (1) may cause other harmful animals to increase; (2) always results in continued benefit to farmers; (3) never results in great harm to anybody; (4) has little effect on the balance of life in its habitat; (5) usually results in the predator's becoming extinct.

7. If certain game animals in a locality are given protection from hunters for a long period, they may increase so rapidly that they suffer from lack of (1) natural enemies; (2) range; (3) water; (4) shelter; (5) food.

8. An animal that is harmful in one locality may be *useful* in another.

Pages 128–133. 9. The McLean Migratory-Bird Treaty protects migratory game birds at *all times.*

10. The Lacey Act forbids the *eating* of game birds killed illegally.

11. Name and explain five ways of increasing the wild-animal population.

12. The best method of increasing desirable wild plants and animals of all kinds is (1) to permit no hunting; (2) to provide suitable habitats; (3) to kill their natural enemies; (4) to raise more of them; (5) to teach more conservation in the schools.

Pages 134–139. 13. Name and explain five methods for the conservation of fish and other water life.

14. State five advantages derived from establishing private fish-ponds.

15. State three possible results of stocking a pond or a stream too heavily with fish.

Pages 140–141. 16. In national parks (1) dangerous animals may be killed whenever seen; (2) game animals may be killed during certain seasons; (3) both plants and animals are fully protected from man; (4) fishing is strictly forbidden; (5) no hunting is ever permitted.

BIOLOGICAL PRINCIPLES · **1.** There is a constant struggle for existence among living things.

2. Living things within a habitat tend to establish a balance of nature which is disturbed more or less seriously whenever any other living things become established there.

3. The environment affects living things, and living things affect the environment.

4. Plants and animals depend on one another in various ways.

5. Species that are not fitted to the conditions about them will not thrive and finally will become extinct.

Applying and Extending What You Know

AS SCIENTISTS WORK AND THINK · **1.** For several years a boy has been raising rabbits as a money-making hobby. Recently he saw a hawk catch and carry off one of his small rabbits. A few days later he saw a large bird flying about near his home. He rushed to get his father's shotgun, intending to shoot the bird. Before he could do so, however, his father called out to him and stopped him. "Do you know whether the bird you see is the same as the one that took your rabbit?" he asked. "Do you know whether that kind of bird eats rabbits?" The boy answered "No" to both questions. "Then why are you trying to shoot that bird?" asked the father.

What scientific attitudes did the father possess that his son did not?

2. For many years farmers and hunters, as well as experts in conservation, have debated whether the crow does more harm than good. Some insist that this bird is so harmful that it should be exterminated. Others say that it does so much good that it should be protected. Plan a scientific way of settling this argument, using the elements of the scientific method listed on page 570.

CONSUMER BIOLOGY · **1.** How does government conservation affect the cost of fur coats?

2. How many kinds of food now available would soon not be if no efforts were made to conserve wild life?

3. How can a farmer raise fish as a money crop?

APPLYING YOUR KNOWLEDGE OF BIOLOGY · **1.** State several ways in which wild life may be harmed when people burn the grass and brush along the edges of fields in the fall or spring.

2. Different kinds of wild life are sometimes imported into a locality to furnish game for hunters. What are some likely results of this practice?

3. What arguments can you state in favor of hunting by airplane, and what arguments can you state against this practice?

4. Deer, raccoons, and other wild animals have been seen frequently within twenty-five miles of New York City. At least one thriving beaver colony has been reported inside the city limits of Los Angeles. What reasons can you suggest which might account for the presence of these wild animals so near great populations of people?

5. Owners of fish-ponds stock them with herbivorous (plant-eating) fish, such as sunfish, and carnivorous (flesh-eating) fish, such as bass. The proportions of these fish are about five sunfish for every bass. Then fertilizers are put into the water to increase the numbers and hasten the growth of the microscopic plants that the herbivorous fish eat. Can you explain how this plan results in a constant supply of both sunfish and bass? To which of the principles above do these facts apply? How do these facts illustrate a food chain?[1] an ecology?[2]

[1]Page 34. [2]Footnote 9, p. 7.

6. Choose sides in the class and have a "spell-down" in which, instead of spelling words, each student gives an example of ecology.[1]

TOPICS FOR INDIVIDUAL STUDY · 1. In an encyclopedia or some other source find the story of how the bison (buffalo), passenger pigeon, or some other native wild animal became extinct.

2. If you live in a rural area, write to your state department of agriculture for pamphlets telling how rats may be controlled. Study these to find out how rats may be killed and how buildings may be made rat-proof. If you live in a city, find out what is being done to control rats. This information may be obtained from the board of health.

WHY NOT BECOME A NATURALIST? · **Biological survey.** Can you determine what kinds of wild-animal life may still be found in your locality? Take a "hike" through open fields, woods, a city park, or a swampy area. Look for and list in your notebook the various kinds of mammals that you see, such as field mice, moles, rabbits, squirrels, and muskrats. Similarly, list the different kinds of birds and other animals (besides mammals). If you do not know the names of some of them, jot down descriptions, or make sketches of them by which you think they might be identified. Record, also, any evidences you may find, such as tracks, nests, and lodges, of animals that you do not see. If possible, go over the same area two or three times and compare the results of each survey. If there are differences, how do you account for them?[2]

COMMUNITY APPLICATIONS OF BIOLOGY · **1. Investigating wild-life protection.** From your state or provincial government obtain a copy of the hunting, fishing, and trapping laws. Study these laws to see how they protect wild life. If you live in a region where lobsters, crabs, and oysters are taken, find out what laws have been passed to protect them. Find out why oysters are sold in the markets, generally, only in the months whose names have the letter *r* in them.

[1]Footnote, 9 p. 7. [2]Pages 104 and 528.

2. Studying artificial wild-life propagation. If there is a fish hatchery or game farm near your home, visit it. Take notes from which you could give a talk in your biology class or your home room or the science club, or from which you could write a paper for your English class or an article for your school paper or magazine.

PROJECT · **To make a bird-house.** From your industrial-arts teacher obtain plans or instructions for building a bird-house for wrens, bluebirds, or martins. Build one or more of these, to be placed in a suitable location in the early spring. When birds occupy the houses, watch them from a distance while they build their nests, incubate the eggs, and raise their young. Keep a record of what you observe.

BIOLOGY IN THE NEWS · Read the columns found on the pages of your newspaper in which information is given about fishing and hunting. Find out what is said about the conservation of fish and game, and what news there is about the release of game from game farms. Note the discussions about the state fish-and-game laws.

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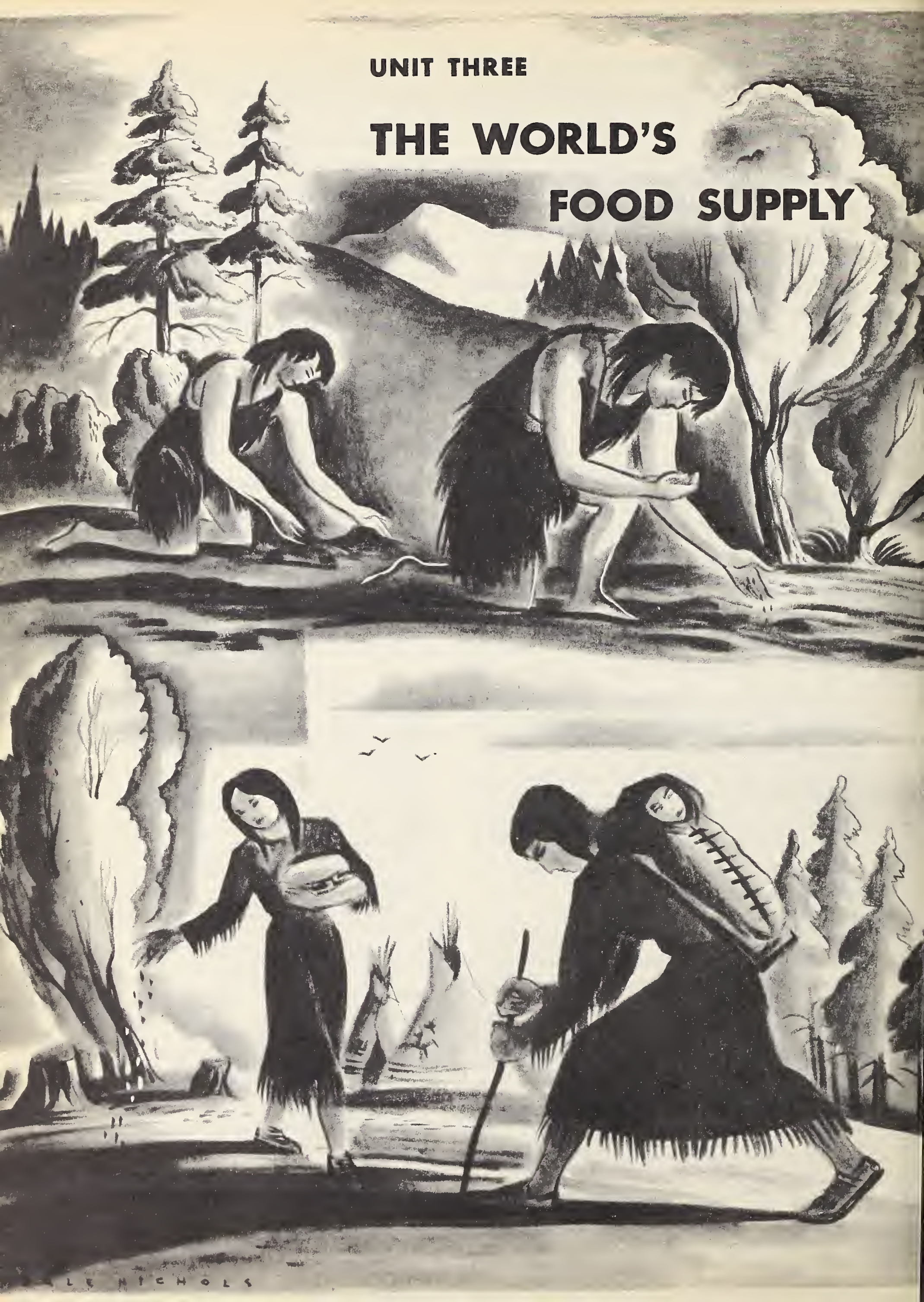
UNIT THREE

THE WORLD'S FOOD SUPPLY



How do chlorophyll-bearing plants make food?

How are the various plant structures related to foodmaking and food storage?

How can we help our plant allies in their struggle for existence?

7

THE MANUFACTURE OF FOOD

1. *How and Where Do Chlorophyll-bearing Plants Make Food?*[1]

If you were to ask the first ten people you might meet, "What are the most important substances in the world?" you would probably get widely different lists. But if you were to ask that question of ten biologists, it is likely that you would find chlorophyll on every list.

Chlorophyll is the green substance that makes green the leaves and some other parts of trees, of plants in vegetable and flower gardens, and, in fact, of most of the plants that are familiar to us. It is one of the most important of all substances because without it there would be no food. Green plants are food factories because the chlorophyll in them enables them to make food. All the animals and all the non-green plants live on the food that green plants, with their chlorophyll, have made (illustration, p. 147).

MONOCOTS AND DICOTS · Where does a young green plant get its food before it has grown large enough to develop food-making structures? The answer is, from the seed from which it sprouted. The flowering plants[2] are divided into two groups, the monocotyledons,*[3] or monocots,[4] and the dicotyledons,*[5] or dicots[6] (illustration, p. 150). A cotyledon**[7] is a seed leaf. This seed leaf is part of a fairly well-formed embryo, which is surrounded, inside the seed, with a store of food. Plants such as oats and corn are monocots because their seeds have one cotyledon.

Plants such as beans, peas, and the common nut plants are dicots because their seeds have two halves, which are the cotyledons. The food stored in a cotyledon enables the young plant to grow and to carry on all its other life processes until it can make its own food.

PROCESSES AND STRUCTURES · The raw materials used by chlorophyll in making food are water from the soil and carbon dioxide from the air. In the higher plants, food is made chiefly in the leaves. In order to understand how water can get from the soil to the leaves, it is necessary to understand the processes of diffusion**[8] and osmosis.**[9] It is necessary, also, to know something about the plant structures concerned with securing and transporting soil water.

DIFFUSION · If you put sugar into a glass containing water and lemon juice and then drink the resulting lemonade without stirring it, it is likely to be sour at the top of the glass

[1]Footnote 5, p. 45.
[2]The angiosperms, p. 563.
[3]*Monocotyledon* (mŏn ō kŏt ĭ lē′dŭn).
[4]*Monocot* (mŏn′ō kŏt).
[5]*Dicotyledon* (dī kŏt ĭ lē′dŭn).
[6]*Dicot* (dī′kŏt).
[7]*Cotyledon* (kŏt ĭ lē′dŭn).
[3]*Diffusion* (dĭ fū′zhŭn).
[9]*Osmosis* (ŏs mō′sĭs).

Howard Jones, Hood River, Oregon

From the time that the first living things appeared on the earth to the present, the chlorophyll in green plants has enabled them to make all the food produced in the world. Where is food being made in this picture?

and sweet at the bottom. But if you were to let it stand long enough, you would find it equally sweet all through, even though you did not stir it at all. This result would follow because of the movements of the molecules*[1] of water, sugar, and lemon juice.

Molecules compose, or make up, every substance, no matter what it is. They are not *in* the substance. They *are* the substance. A molecule is the smallest particle of any substance that can exist by itself. Molecules are so minute that not all are visible even with an electron microscope (illustration, p. 404).

Molecules are made up of still smaller bodies called atoms.[2] There are only ninety-six different kinds of atoms. There is one kind for each of the ninety-two natural elements and one for each of the four man-made ones.[3] Some molecules have only a single atom each. Examples of such molecules are those of mercury and silver, each of which has one atom of the element mercury or silver. Other molecules are made up of large numbers of atoms of several different elements. A molecule of common table sugar, for example, is made up of forty-five atoms.

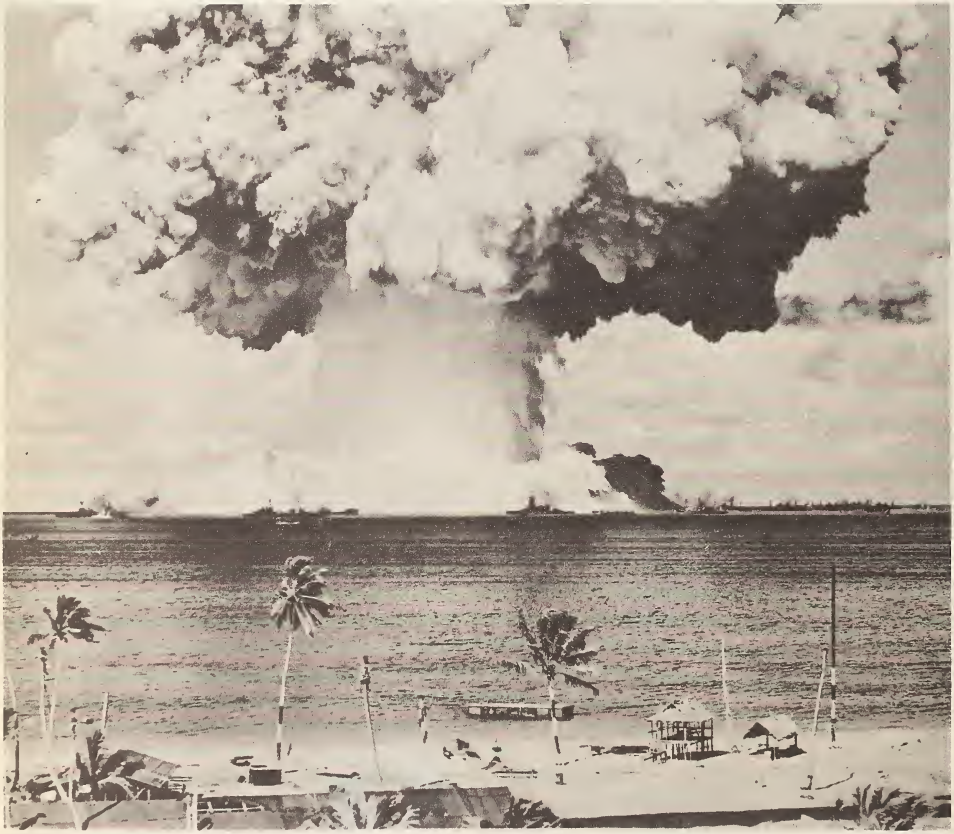
[1]*Molecule* (mŏl′ē kūl).

[2]*Atom* (ăt′ŭm).

[3]Pages 64–65.

ATOMIC RESEARCH

WHENEVER WE HEAR or read about "atomic fission" or "atomic research," we are likely at once, with fear and dread, to think of the atomic bomb. It is proper that we should. For it is believed possible that progress in applying atomic research to means of destruction *could* end in destroying civilization, if not all human life. We should constantly remember, however, that the atomic research



International

The atom-bomb explosion under water at Bikini in July, 1946. Topic for Individual Study: The biological implications of atomic research for constructive and destructive purposes

which enabled our scientists to make the atomic bomb, and with it to end our recent war with Japan, holds possibilities for benefiting mankind beyond our present dreams.

Atomic research has already opened many doors to biological science. "Atomic scientists" are already experimenting with "radioactive isotopes[1]" in a bewildering number of ways. Radioactive isotopes, or "tagged substances," are elements and compounds that give off "rays." These rays can be detected and studied in the bodies of plants and animals, just as they can in non-living materials. To illustrate, by means of radioactive carbon scientists have already made considerable progress toward discovering the various steps in the complex process of photosynthesis. When all these chemical actions have finally become known, it may, at some future time, be possible to invent and carry out ways of making food from carbon dioxide and water, as green plants do, but without any help from green plants! Can you imagine a world in which food crops would not be important, and yet a world in which there would always be abundant food for everybody?

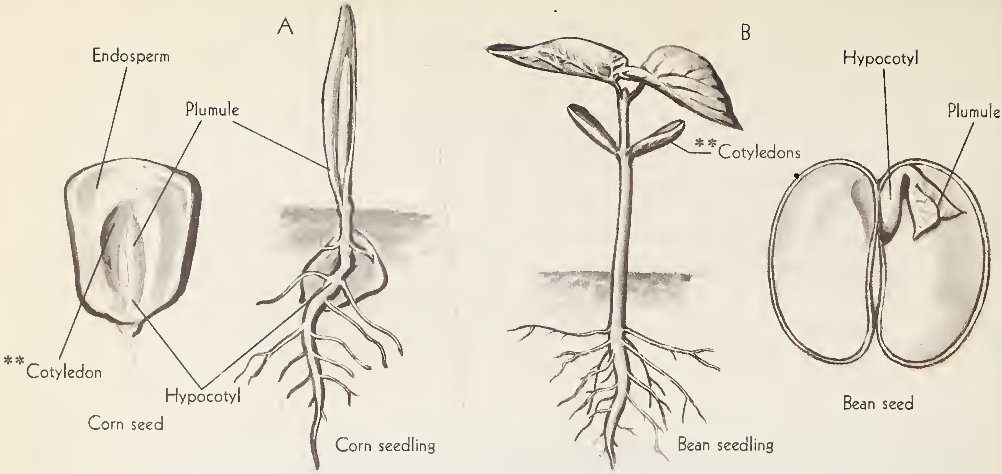
By means of tagged substances scientists are able to investigate diseases far more effectively than ever before. Thus they are studying tagged tuberculosis bacteria in the hope of being able to discover how such germs invade the body and attack its structures. Such scientists are learning, with increasing success, how to use radioactive substances in treating serious diseases. These diseases include (to name only a few) disorders of the white blood cells, the lymphatic glands and other lymphatic tissues, the spleen, the thyroid gland, and the heart.

Still other scientists are experimenting with radioactive substances in drugs. One result that is expected, when these drugs have finally been perfected, is that they will increase the resistance of the body to cancer.

Agricultural chemists are experimenting with radioactive substances to find out how plants use the minerals which they obtain from the soil. Thus these scientists are making progress toward improving crops and increasing their yields. By extending these studies to the grasses of pasture lands, the scientists hope to make possible a greater abundance of meat and milk.

The examples given here merely suggest some of the kinds of experiments which scientists in all fields of biology are carrying on in all parts of the world. Keeping informed on the progress of this research is a facinating adventure. Who knows at what moment the radio and the newspapers may announce a new development of atomic research which will change completely our ways of life!

[1]*Isotope* (ī'sō tōp).



The seeds of pine trees and most other evergreens have more than two cotyledons. Compare the bean and corn seeds, stating the respects in which they are alike and those in which they are different

$C_{12}H_{22}O_{11}$ - sugar

Twelve are atoms of carbon; twenty-two, of hydrogen; eleven, of oxygen. Some molecules are composed of hundreds of atoms.

For all practical purposes the molecules of different samples of the same substance are always exactly alike because all are composed of atoms of the same element or elements. Molecules of different substances are different from one another because each kind of molecule is composed of a different combination of atoms from that which composes any other kind. For that reason substances are different from one another in color, hardness, odor, and all other properties because their molecules are different. Their molecules are different because they are composed of different numbers, kinds, and arrangements of atoms.

Atoms are composed of still smaller units called electrons,[1] protons, and neutrons. The electrons move around a central group (nucleus) of protons and neutrons in somewhat the same way that the planets circle around the sun, and the moon around the earth. Electrons are studied in more detail in physics and chemistry than in biology.

[1]*Electron* (ē lĕk′trŏn).

Molecules are not alive; yet all molecules are constantly moving about. Some of them travel faster than bullets from guns, but usually for microscopic distances. The higher the temperature, the faster they move. Hence, in a glass of lemonade, the molecules of each kind, those of sugar, of water, and of lemon juice, travel in all directions by their own motions. Those of each kind tend to scatter out from where they are most closely concentrated (packed together) to portions of the liquid where they are farther apart. After a time the molecules of each kind become equally distributed throughout the liquid.

The process by which substances of different kinds become mixed by the movements of their molecules is known as diffusion. If you were to spill perfume or ammonia in a closed room, you would soon be able to smell it in every part of the room because the mole-

cules of the perfume or the ammonia would rapidly diffuse[1] (that is, scatter, or disperse) throughout the room.

OSMOSIS · How water and perhaps also minerals and other substances dissolved in water can pass through cell walls may be indicated by an experiment set up in the way shown in the diagram on this page. If you make the levels of the water and the sugar solution the same at the beginning and then observe these levels on the following day, you will find the level of the water in the tumbler below that of the sugar solution in the funnel.

[E]The explanation of this observation is this: The surface of a membrane,**[2] or thin sheet of tissue, such as the cellophane or parchment used here, appears to be unbroken. Actually it is not. It contains numerous microscopic pores. The molecules of many substances will find their way through the minute holes in the moist walls of the individual cells. Thus they will diffuse into or out of plant or animal tissues.

Usually, though some exceptions have been found, the molecules of one kind pass by osmosis through a moist membrane from the side of it where they are more closely packed together (concentrated) to the other side, where they are farther apart. In the osmosis of sugar and water just described, the molecules of each of the two substances passed through the membrane from the side where they were more highly concentrated to the side where they were less highly concentrated.

[E]Different kinds of molecules do not diffuse through a moist membrane with equal ease.[3] Some are believed not to pass through at all. In the experiment both kinds of molecules passed through the membrane, but the molecules of water did so much more readily than the molecules of sugar. The probable reason why they did is that water molecules are smaller and move faster than sugar molecules. Consequently several or, perhaps, many water molecules went into the thistle tube for every sugar molecule that came out.

[E]The special type of diffusion by which the molecules of a substance pass through moist cell walls and cell membranes is called osmosis.**[4]

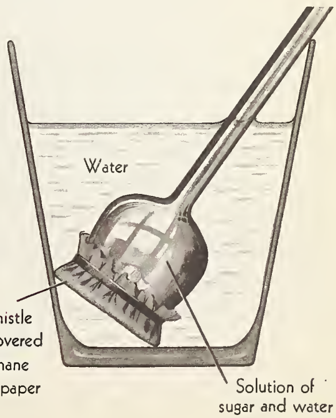
[1]*Diffuse* (dĭ fūz'). [2]*Membrane* (mĕm'brān).

[3]A membrane through which some substances in a solution—that is, dissolved substances—pass readily, but others do not, is known as a *semipermeable* (sĕm ĭ pûr'mē *ȧ* b'l) or *differentially* (dĭf ẽr ĕn'shăl ĭ) permeable membrane.

[4]Biologists agree that osmosis is a common process in plants and animals. They are not yet certain, however, of the true nature or explanation of it. Some believe that water is the only substance that can be osmosed (ŏs'mōst). The definition just stated and the discussions here and elsewhere in this book are in harmony with the opinion of probably the majority of scientists, who believe that osmosis takes place not only with water, but also with some other liquids and with various gases and solids in solution.

Osmosis does not entirely account for the passage of materials into and out of living cells. Scientists believe that the passage is aided and perhaps controlled by some action of the cells, not yet understood.

Osmosis apparatus · No control (p. 570) is indicated here. Can you suggest how a control might be introduced?



[E]Energy is the capacity, or ability, to do work. In the scientific sense work is done only when something is made to move. Anything possesses energy if it is moving or if it can make something else move. Energy exists in a number of forms. Those of special interest in biology are (1) stored energy, such as the chemical energy of food; (2) the energy of heat; (3) the energy of light; and (4) the energy of movement. What evidences of these forms of energy can you find here?

PLANT STRUCTURES AND SOIL WATER · If you plant some seeds of beans or peas in moist sawdust, they will sprout in a few days. If then you examine them carefully, you will see on each root a fuzzy mass of minute, hair-like growths. These are root hairs. A root hair is an extended part of a certain type of cell of the epidermis,**[1] or outer covering, of the root (illustration, p. 155).

[1]*Epidermis* (ĕp ĭ dûr′mĭs).

[P]All the water which a plant uses enters it through its root epidermis. The root hairs grow outward in all directions among the soil particles. Thus they enormously increase the absorbing surface of the epidermis. Every large plant must have a vast number of root hairs in order to be able to secure as much as it needs of water and dissolved minerals from the soil.

[E]Inside the epidermis of the root is a cylinder-shaped region of larger cells. This is the

cortex.*[1] The epidermis and the cortex together protect the central cylinder, which contains the fibrovascular[2] bundles** (illustration, p. 155, bottom). The fibrovascular bundles contain supporting fibers and tube-like cells, through which liquids readily pass. The fibrovascular bundles in the roots join with similar ones running through the stems and into the branches, and thence extend as veins** into the leaves. Thus they make up a continuous vascular (transportation) system, through which sap, with dissolved foods and minerals, passes to all living parts of the plant.

Water in the spaces among the soil particles and on their surfaces enters the plant by osmosis through the walls of the root hairs. From the root hairs it passes by osmosis from cell to cell through the cortex of the roots into the fibrovascular bundles. Here it passes upward through the stem and the branches into the leaves. There much of it is transpired, or given off as vapor, into the air.

LEAF STRUCTURES · **The protective structure.** The top of the leaf is covered by the upper epidermis, and the bottom by the lower epidermis (illustration, p. 155). Each of these is a thin, skin-like tissue composed of a single layer of flat cells. It protects the delicate structures inside the leaf, just as the epidermis, or outer skin, of one's body protects soft structures within.

The leaf epidermis is transparent. Hence the sunlight passes through it to the chlorophyll in the leaf as readily as sunlight passes into a room through a window-pane. A wax-like substance (cutin[3]) usually covers the epidermis. It prevents water from being evaporated by the sun's energy in too great quantities from the outside of the leaf, and also it makes the surface water-proof (illustration p. 152).

Openings into the leaf. Scattered thickly about in the lower epidermis are stomata.*[4] A stoma, or stomate,[5] is a slit-like opening between two special cells, called guard cells. The guard cells are usually the only cells in the epidermis that contain chloroplasts (legend, illustration, p. 155, bottom). Hence they are the only epidermal cells that can take part in the food-making.

Each stoma is smaller than the smallest dot that you can make with a pencil point, and can be studied only with a microscope. The stomata are the only means by which air can enter the leaves and gases produced within the leaves can escape.

The only part of the air which the plant uses in making food is carbon dioxide. Only a small part of the air is carbon dioxide—in fact, only three hundredths of 1 per cent, or three parts of carbon dioxide in every ten thousand parts of air. You may wonder, therefore, how enough carbon dioxide can get into the leaves, through such extremely small openings as the stomata, to supply the great quantities needed for food-making. This is possible because the stomata are so numerous. Though the numbers vary in different kinds of leaves, there are sometimes twenty-five thousand or more stomata in one square inch of leaf surface. A single large leaf may contain many millions.

The food-making cells. The stomata open into spaces among the cells of the spongy tissue of the leaf. Above the spongy tissue is the palisade*[6] tissue. Only one layer of palisade cells is shown in the simple diagram on page

[1]*Cortex* (kôr′tĕks).

[2]*Fibrovascular* (fī brō văs′kū lẽr).

[3]*Cutin* (kū′tĭn). Scientific terms in the text and in the illustrations are not intended as essential vocabulary unless they are marked with two asterisks (**). They are included so that you may build a large biological vocabulary if you wish to do so.

[4]*Stomata* (stō′mȧ tȧ; singular, *stoma* (stō′mȧ).

[5]*Stomate* (stō′māt).

[6]*Palisade* (păl ĭ sād′).

Chlorophyll catalyst

155, though a leaf may have several. The cells of the spongy tissue and the palisade tissue contain enormous numbers of chloroplasts. Hence food is made in all these cells, though the palisade cells serve as the chief food factories.

Functions of the veins. The veins**[1] of the leaves not only (1) supply the water needed by the food-making cells, but also (2) carry away the manufactured food. A third function of the veins is to (3) supply a frame, or skeleton, which supports the leaf surface and spreads it in the sunlight (illustration, p. 156).

The cells of the veins have no chloroplasts. Hence none of these cells nor of those of the epidermis except the guard cells make food. Instead, they get the food they need, probably by osmosis, from the leaf cells that make it.

The food-making process, photosynthesis.[2] ᴱThe surfaces of the food-producing cells within the leaf are constantly moist with water. Carbon dioxide, entering through the stomata, dissolves in this water and passes by osmosis through the moist cell walls. When sunlight strikes the chlorophyll within the leaf, a chemical action results in which the water and the carbon dioxide combine to form sugar. The process by which water and carbon dioxide are made into food by chlorophyll, with the aid of energy furnished by sunlight, is called photosynthesis.

Sugar produced in the leaf cells is dissolved in the plant sap and passes by osmosis into the veins. Thence it is transported through the fibrovascular bundles to all parts of the plant, as will be explained more fully later.

[1] *Vein* (vān).

[2] *Photosynthesis* (fō tō sĭn′thē sĭs). The word *synthesis*, whether it occurs alone or as part of another word, means the building of chemical compounds by combining two or more substances (elements or compounds or both). *Synthesize* (sĭn′thē sīz): to bring about a synthesis of materials. *Synthetic* (sĭn thĕt′ĭk): produced by synthesis.

ᴱGreen plants, besides being the only organisms that manufacture food, are the only organisms that produce oxygen. The oxygen is given off as a by-product, or waste product, of the process of photosynthesis. It passes through the moist cell walls, probably by osmosis, into the air spaces among the cells of the spongy tissue. Thence it diffuses out through the stomata. Water is constantly evaporating from the surfaces of the moist cell walls into the air spaces within the leaf. It likewise transpires, or diffuses out through the stomata.

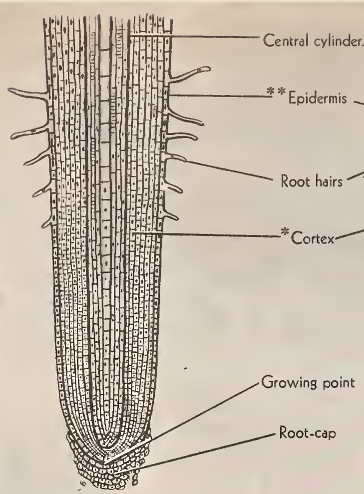
Photosynthesis in deciduous and evergreen trees. Probably the bushes, shrubs, and trees with which you are most familiar are the deciduous*[3] ones. These grow new leaves in the spring and lose them in the fall or earlier (illustration, p. 158). The young deciduous plants have chlorophyll in their stems, which makes some food throughout the year. The older deciduous plants lack chlorophyll in their stems. Hence they must make and store enough food while they have their leaves to enable them to survive during the months when they have none.

The trees and shrubs that are green all through the year are called evergreens.*[4] Evergreens lose their leaves, but only a few at a time. Therefore they always have the means of making food. Hence they do not have to manufacture it so rapidly, or store it in such large quantities, as the deciduous trees.

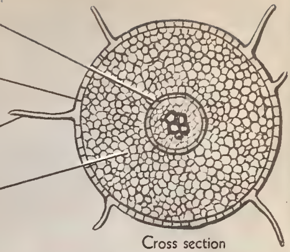
RESPIRATION · ᴱᴾEvery living cell, whether it is an animal cell or a plant cell, is constantly using energy stored in food. This food serves as fuel, which is burned, or oxidized (combined with oxygen), in the cell. The cell must therefore be continuously supplied with oxygen, as well as with

[3] *Deciduous* (dē sĭd′ū us). [4] Pages 562–564.

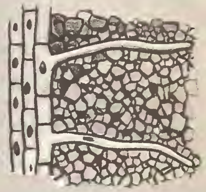
Corn root
with root hairs



Longitudinal section of young root



Cross section
of young root

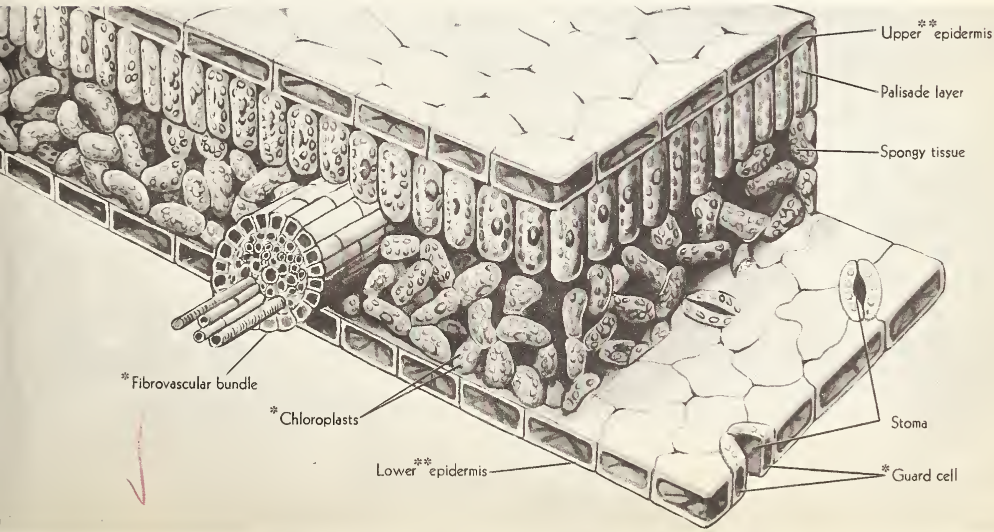


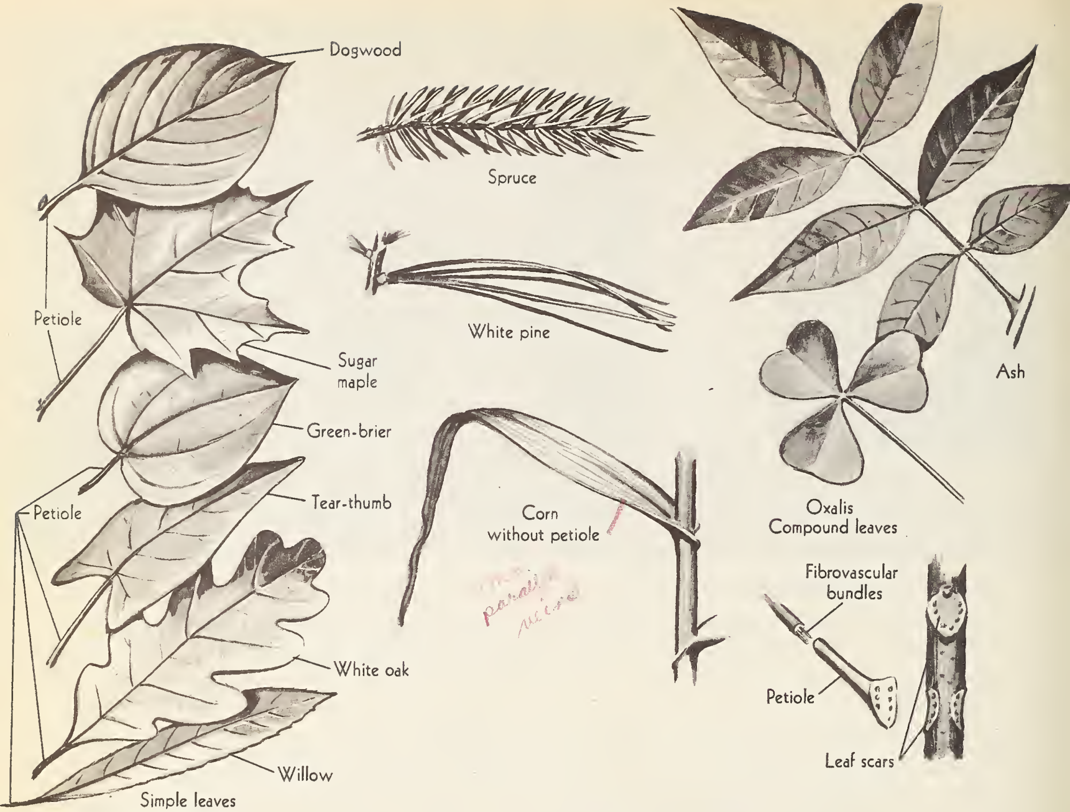
Root hairs in soil

The structures of a plant root · When a tree is transplanted, usually most of its branches and leaves are first removed. Can you explain why? In transplanting plants, why must the roots not be allowed to become dry?

Typical leaf structures · The food-making bodies in higher green plants are the chloroplasts.*[1] In most green plants these are tiny grain-like bodies composed of protoplasm and chlorophyll. Some of the simplest plants contain chlorophyll, but no chloroplasts. Summarize all that you have learned about chlorophyll thus far

[1]*Chloroplast* (klō′rō plăst).





Typical leaf forms · How is each adapted to present a broad surface to the sunlight? What functions do you think are performed by petioles? **Topic for Individual Study:** Secure leaves of as many types as you can. Observe their forms, margins, and veins. In textbooks of botany try to find out what terms, such as *pinnate-veined*, *lobed*, and *compound*, are used in describing different leaf forms. Find out how a botanist can usually tell from the leaves whether a plant is a monocot or a dicot

food. The burning, or oxidation,**[1] changes the chemical energy stored as food into heat energy, and into the energy that is needed for movement, growth, and all the other activities and life processes of the organism.

EP Whenever food is oxidized in a cell, water and carbon dioxide are given off as waste products. The processes by which a plant or an animal takes in oxygen and gives off carbon dioxide is called *respiration*.**[2] In higher animals breathing is part of the process of respiration.

PHOTOSYNTHESIS AND RESPIRATION · Every living cell in a plant, whether it can produce food or not, carries on respiration all the

[1] *Oxidation* (ŏk sĭ dā'shŭn).

[2] *Respiration* (rĕs pĭ rā'shŭn).

time. Every food-producing cell carries on photosynthesis also during the daylight hours. Therefore the two processes, respiration and photosynthesis, are both going on at the same time in every green plant during the hours of daylight. But only respiration is carried on by green plants during the hours of darkness.[1]

In carrying on photosynthesis the plant cell can make use of the carbon dioxide and the water that result from its own respiration. But it needs much more of both than is thus produced. Hence, during the day, it secures additional carbon dioxide from the air and additional water from the soil.

In oxidizing food the cell can use oxygen which results from its own photosynthesis. But while photosynthesis is going on, the cell produces more oxygen than it needs for oxidizing food. The surplus oxygen escapes into the air. At night, however, when the cells are not carrying on photosynthesis, they must take all the oxygen that they need from the air that enters the leaves through the stomata.

[1]The results of recent investigations indicate that the energy of sunshine is needed for only the first few stages of photosynthesis, and that later stages can be carried on by green plants in darkness.

SUMMARY · The comparison of photosynthesis and respiration just made may be summarized as shown in the chart below.

THE OXYGEN–CARBON-DIOXIDE CYCLE · [E]The oxygen given off by green plants in photosynthesis is used by animals in respiration. The carbon dioxide given off by animals in respiration is used by green plants in photosynthesis. Hence, [P]there is a constant exchange of oxygen and carbon dioxide between green plants and animals. This endlessly repeated use of oxygen and carbon dioxide is called the oxygen–carbon-dioxide cycle (illustration, p. 160).

THE STRUGGLE FOR SUNLIGHT · During long periods of time each kind of plant has developed a form that is well adapted, or suited, to exposing its leaves to the sunshine. If you observe any well-leaved plant, you will note that the leaves and branches grow in such a way that a relatively small proportion of the leaves shade one another. Thus the plant is able to make the most of the light that strikes it. It can survive only if enough of its chlorophyll is exposed to the sunlight to make all the food that it needs (illustration, p. 159).

PHOTOSYNTHESIS: GREEN PLANTS ONLY, IN DAYLIGHT ONLY

(Chlorophyll) + (Energy in the form of light) + (Water from the soil) + (Carbon dioxide from the air) —Results in→ (Energy stored in food) + (Oxygen as a waste product)

$6H_2O + 6CO_2 \rightarrow C_6H_{12}O_6 + 6O_2$

glucose

RESPIRATION: ALL PLANTS AND ALL ANIMALS, ALL THE TIME

(Energy stored in food) + (Oxygen from the air) —Results in→ (Energy in the forms of heat, movement, etc.) + (Water as a waste product) + (Carbon dioxide as a waste product)

All the plants in any spot compete with one another for the sunshine. This struggle is a constant and vigorous one, and only a small proportion of the green plants that begin life are successful in getting enough light to survive. The ones that are stronger and can grow faster, shade and thus starve to death the weaker ones. When, for example, a great tree in a dense forest falls and a space is thus opened to the sunshine, many young trees grow to fill this space. One by one the stronger, faster-growing ones shade and thus starve the weaker ones. After many years of such competition, the struggle is likely to be won by just one great tree (illustration, p. 161).

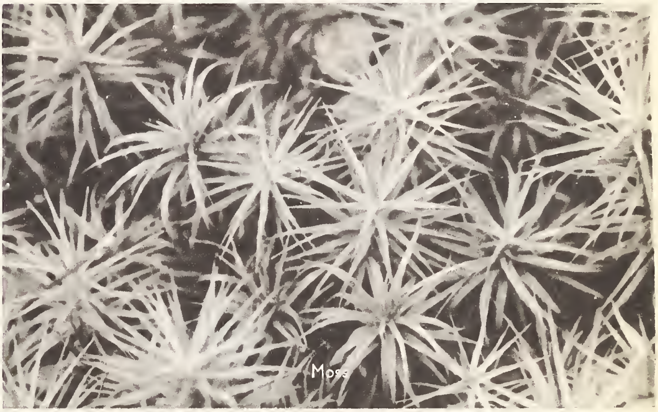
The competition for light goes on not only between different plants, but also between different parts of the same plant. Thus, if the upper branches of a tree shade the lower ones, the latter will die and drop off. This process is known as self-pruning. Likewise, if the leaves on part of a branch become shaded by other leaves, the shaded ones will drop off.

Man makes use of his knowledge of the struggle of green plants for light to control them for his advantage. For example, he plants his orchard trees and garden plants far enough apart so that they will not compete with one another for light. In contrast, in planting forest trees he sets them close together so that, as they grow, the lower branches will be shaded, will die, and will drop off. As a result, long, straight trunks are left, which are clear of knots and thus are suitable for lumber.

Deciduous and evergreen trees · Compare them by listing in parallel columns the ways in which they are alike and the ways in which they are different

United States Forest Service

gh Spencer



Leaf adaptations for securing sunlight
How does each differ from the others?
Topic for Individual Study:
In a textbook of botany look up rosette plants, leaf mosaics, and alternate arrangements of leaves. Do the plants shown here illustrate any of these types? Justify your answer.

2. *What Stem Structures Are Related to Food-making?*

In the simplest green plants, the one-celled algae,[1] the entire food-making process is carried on independently by each cell. Water and the carbon dioxide dissolved in it pass by osmosis through the cell wall directly into the cell. The chlorophyll within the cell manufactures food. Surplus oxygen, which results from photosynthesis and which is dissolved in water, passes by osmosis out through the cell wall. No special structures are needed for transporting materials into, within, or out of such simple plants.

In general, the lower the plant in the scale of life, the more simple are the structures that distribute food, water, and other materials throughout its body. Mosses,[2] for example, have no transportation[3] system, though they have structures resembling leaves, stems, and roots. In these relatively simple plants, materials pass from cell to cell by osmosis. In contrast, in the highest plants,[4] the leaves, where the food is made, may be hundreds of feet from the roots, where the water enters the plants. Such plants could not exist without complex vascular, or transportation, systems.

[1]Page 555. [2]Page 559. [3]Page 153. [4]Page 562.

The oxygen–carbon-dioxide cycle · Bulletin-Board Display:
Make an original drawing illustrating this cycle

ᴱSeveral facts about the vascular system of a typical higher plant have already been stated: The system is made up of the fibrovascular bundles. The fibrovascular bundles in the roots, stems, branches, twigs, and leaves are connected to form one continuous system. Water passes up from the roots through the fibrovascular bundles to the leaves, and food passes from the leaves through the fibrovascular bundles to all parts of the plant. A study of stems will reveal other facts about the vascular and other structures (illustration, p. 162).

STRUCTURES OF A DICOT STEM · *The fibrovascular region.* In a young dicot stem the fibrovascular bundles are separate and are arranged in a broken circle inside the stem. Practically the entire stem of a young plant, except the fibrovascular bundles, is made up of thin-walled living cells. As the plant grows, the bundles increase in size and finally close the spaces in the circle. Thus they form a tall, vertical cylinder which extends through the entire stem. The thin-walled cells which are surrounded by this cylinder die and become the pith.

While the bundles are growing together, they are compressing the cells that separate them. By the time the cylinder of bundles is complete, these cells have died and have been squeezed into pith rays (or medullary[1] rays). Pith rays are vertical sheets of soft tissue, perhaps half an inch or more high, extending, between the fibrovascular bundles, from the

[1]*Medullary* (mĕd′ŭ lĕr ĭ).

pith region in the middle of the stem to the outside. They convey sap to parts of the stem that are not directly served by the vascular, or circulatory, system.

A fibrovascular bundle of a dicot is made up of three important groups of cells, or tissues. These are the xylem,*[1] the phloem,*[2] and the cambium.*[3] The xylem is on the inside of the stem, the phloem toward the outside, and the cambium between the phloem and the xylem.

The xylem consists of thick-walled, tubelike wood cells, among which are some fibers. These cells serve two important functions: (1) they carry water upward from the roots to the leaves, and (2) they provide the chief support of the plant.

The phloem consists of thin-walled, tubelike cells and usually also many fibers (bast fibers). This stem region carries dissolved food from all parts of the plant where food is made to the parts where it is used by the cells or is stored. In some parts of a plant, therefore, the sap moves upward and in others downward through the phloem (illustration, p. 162).

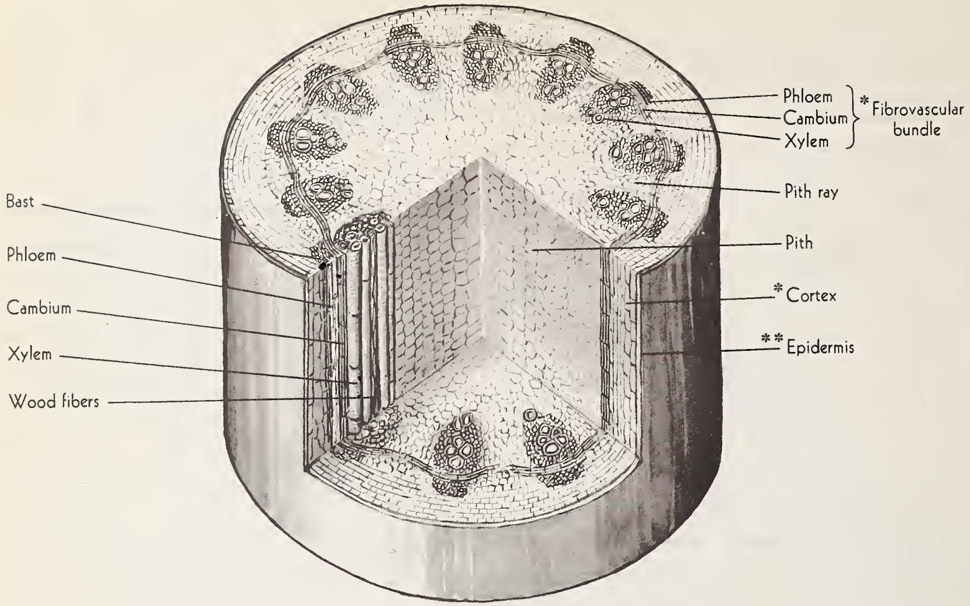
Perhaps you have seen a tree that has been "girdled" to make it die. In girdling a tree, a deep ring is cut around the stem entirely through the bark. When the phloem is cut through, food from the leaves cannot go down into the roots. The girdled plant will usually live during the rest of the season because (1) water is able to go to the leaves through the xylem, and hence photosynthesis can go on, and (2) there is enough food stored in the roots to supply for a while the energy that the plant needs. But the following year, or whenever the reserves of food in the roots have become exhausted, the tree will die.

The cambium is the region of growth. It is responsible for all the increase in the stem's thickness except that resulting from normal growth processes which take place in all young tissues, by the increase in the number of cells and by their enlarging to full size. The cambium produces not only new cambium cells, but also, on the inside of the cambium layer, new xylem cells and, on the outside, new phloem cells. As the cambium layer slowly enlarges, it crowds the xylem and phloem farther apart. As the plant grows, moreover, the cylinder of fibrovascular bundles in-

This "wolf tree" is a white oak in a grove of pines. Its stem is nearly three feet in diameter. It has starved to death all other trees in a circle sixty feet in diameter and thus has eliminated them. Lumber-men usually destroy such "wolf trees." Why?

United States Forest Service

[1]*Xylem* (zī′lĕm). [2]*Phloem* (flō′ĕm).
[3]*Cambium* (kăm′bĭ um)



In what ways do you think that this section of a young dicot stem would differ from a similar section of an old dicot stem?

creases in diameter and shifts farther from the center of the stem, like a slowly enlarging ring.

As a dicot develops new xylem cells, the pith is squeezed into a smaller space. In perennial[1] dicots, such as trees, it may even disappear. In annual[1] dicots, such as bean and sunflower plants, the woody region is merely a narrow, circular band. Hence the pith may occupy much of the middle of the stem. Whenever the pith breaks down, as it does in many annual dicots, the middle of the stem becomes hollow (illustration above).

The protective structures. Outside the phloem is a region of living cells called the cortex. The cortex and the phloem together make up the bark, though what we usually think of as the bark of a tree is developed from the outer cells of the cortex. Cork is formed in the walls of these cells, which therefore become thicker. In time the cells die and become dry.

In young stems the cortex is covered by a thin tissue of epidermis. Both the cortex and the epidermis are protective structures. As a tree grows, the epidermis, and, in some cases, the corky outer bark also, cracks and splits under the strain caused by the increasing diameter of the stem. The epidermis, together with much of the outer bark, flakes, peels, or breaks off. In this way the old bark of many kinds of trees is weathered off about as fast as new outer bark forms. In many kinds of evergreens, however, the corky region increases in thickness faster than it is weathered. For example, the bark of a sequoia of California occasionally becomes thirty or more inches thick and has been

[1]Page 563.

Anderson, from National Park Service

The Telescope Tree, Yosemite National Park · The heart of this sequoia tree was burned out long ago. A person standing inside the tree can look up through it and see the sky. How do you explain the fact that the tree is still alive?

ANNUAL RINGS

known to protect the tree from forest fires that destroyed all other vegetation in the groves.

The epidermis of a young stem or twig has stomata. As the stem or twig develops bark, the stomata change to pore-like openings through the bark, called lenticels*[1] (illustration below). If you examine the bark of cherry or birch, you will see the lenticels as dots. Through these, oxygen reaches the living cells of the stem, and the carbon dioxide and the water vapor which result from respiration in the cells escape through them.

FOOD-MAKING AND GROWTH · Plant stems and branches grow in height or length by the growth of buds. A bud** is a structure at the end or on the side of a stem or a branch, which contains a tiny stem to which are attached immature leaves or flower parts, or, in some cases, both (illustration below).

A plant root grows in length as new cells are formed by a growing point near the root-cap. As has been indicated, a dicot plant stem or branch grows in diameter as the cambium region of the fibrovascular bundles produces new cells.

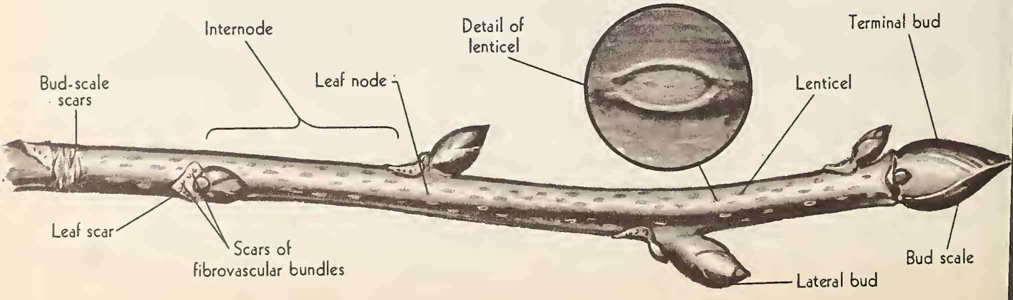
[1]*Lenticel* (lĕn′tĭ sĕl).

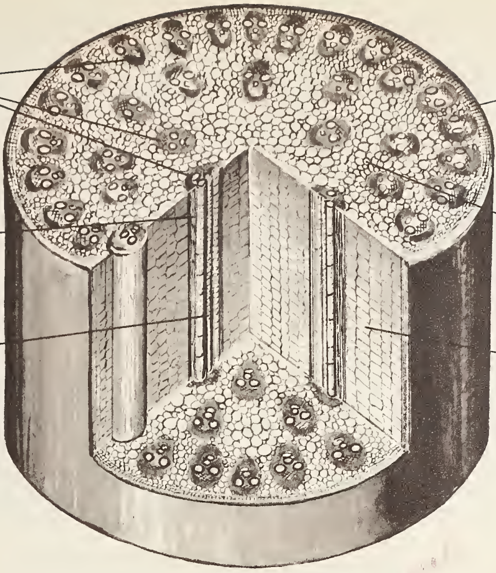
In the spring the growth of a tree is rapid. The plant needs to make food rapidly for the production of new cells. Hence the xylem cells formed by the cambium in the spring must be large in order to carry to all parts of the plant the supplies of water and minerals required for food-making and growth. Later in the season, however, when the growth of the plant is less rapid, smaller, thick-walled xylem cells are formed. As a result, a growth ring composed of these two types of wood cells is formed each year in the stem. Each ring is formed outside the ring produced during the preceding year. By counting these growth rings one can determine the approximate age of a tree.

There are growth rings only in the woody region of the stem. As new phloem is formed, the old phloem layer, outside it, dies. The old phloem, however, does not form rings, as does the old xylem tissue. It cannot, because, in contrast with the xylem cells, the phloem cells have thin walls, which are crushed as the new bark is formed.

All but the outer portions of the stem of an old tree, then, consists of dead wood, which is hard and dry. It is made up of vertical layers, or rings, in the form of cylinders, one inside the other, with the oldest ones toward

Buds on twigs · In the bud are all the structures that will develop later. Bud scales are modified leaves. They over-lap and thus prevent water from entering the buds. Also, they protect the buds, more or less, against cold, insects, and blows. **Topic for Individual Study:** How do leaf buds, flower buds, and mixed buds differ from one another? (Consult a textbook of botany)





Section of a monocot stem · Compare the monocot and dicot stems (illustration, p. 162) by stating ways in which they are alike and ways in which they are different

the middle. The older the tree, the more of these layers of wood it has, and consequently the greater is the support provided for the heavy top. Outside the wood is the relatively narrow cylinder containing the fibrovascular bundles. Outside these, on an old stem, is bark, and, on a young stem, epidermis.

STRUCTURES OF A MONOCOT STEM · In a monocot stem the fibrovascular bundles do not form a cylinder. Instead, in a pithy-stemmed monocot, bundles are scattered through the pith, but are more numerous toward the outside (illustration above). You can get a clear idea of how the bundles extend through such a monocot by breaking a sugar cane or the stalk of a corn plant or cattail plant, and pulling it apart a little as you break it. You will see the fibrovascular bundles sticking out of the pith as tough strings. In hollow-stemmed monocots, such as bamboo, wheat, and other grasses, all the fibrovascular bundles extend upward through the hard, rind-like outer structure.

Only the young fibrovascular bundles of a monocot have cambium. Like the fibrovascular bundles of a dicot, these bundles produce phloem and xylem tissue, but, unlike them, they do not form more cambium cells. As a result, the stems of monocots do not increase greatly in diameter, as do dicot stems. They grow somewhat thicker, however, (1) as new cells form and grow to full size and (2) as new fibrovascular bundles form.

The xylem and phloem regions in the bundles of a monocot perform the same functions of transporting sap as do the corresponding regions in dicot stems (illustration, p. 162).

DIVISION OF LABOR · (A SUMMARY.) The functions performed by various structures of a green plant, as described in this chapter and earlier, provide an excellent example of division of labor.

E In the leaf the stomata allow air to enter the leaf and water vapor and oxygen to leave it. The chlorophyll within the chloroplasts of the food-making cells carries on the chemical processes of photosynthesis. The fibrovascular bundles which make up the veins bring water and minerals to the food-making cells and transport the manufactured food to all the living parts of the plant.

E In the stem the bark protects the structures within. The phloem transports food, the cambium (of dicots and young monocots) produces new cells, and the xylem carries sap upward to the leaves.

E In the roots the cells of the root hairs take in soil water, which contains dissolved minerals. The fibrovascular bundles of the root join with those of the stem and perform the same functions of growth and transportation of sap as do those of the stem.

E Each structure has its own special work to do. The failure of any one kind of structure to do its part in the division of labor would sooner or later result in the death of the plant.

Checking What You Know

BIOLOGICAL FACTS · (*Do not write in this book.*) **Pages 146–159.** **1.** All the food in the world is made by --?-- plants.

2. You are an *independent* organism.

3. State five or more facts about molecules.

4. Select from the following the one that does not possess energy: (1) a piece of candy; (2) a pebble lying on the level ground; (3) a flying insect; (4) an unlighted candle; (5) a lighted candle.

5. In your own words compare diffusion and osmosis by stating both the ways in which they are alike and those in which they are different.

6. The important root structures, in their order from the outside of the root to the middle, are *epidermis, fibrovascular bundles, and cortex*.

7. Water containing food and other dissolved substances passes through the *fibrovascular bundles* to all parts of a plant.

8. Most of the food manufactured by green plants is made in the cells of the (1) roots; (2) stems; (3) fibrovascular bundles; (4) leaves; (5) roots, stems, and leaves.

9. *Food* passes into leaves through openings called stomata.

10. Plant cells which cannot make their own food obtain it by the process of *transpiration*.

11. The grain-like bodies that carry on photosynthesis are *chlorophyll*.

12. The three functions of leaf veins are --?--, --?--, and --?--.

13. Oxidation, or burning, in living cells is always accompanied by (1) light; (2) heat; (3) neither light nor heat; (4) both light and heat; (5) the destruction of the cells.

14. Explain in your own words how photosynthesis and respiration are opposite processes.

15. *Deciduous* trees make food during the entire year.

Pages 159–166. **16.** Water passes upward through the *cambium* region of the fibrovascular bundles.

17. Name in order, beginning at the outside, the stem structures of a dicot. State in your own words one or more functions of each.

National Park Service

Historical facts can often be determined from a study of growth rings. For example, scientists have found out in this way that the Indians who built these cliff dwellings in Mesa Verde National Park, Colorado, left their homes in 1295, after twenty-four years of continuous drought. Do you think the timbers of these houses were made from monocots or dicots? Explain

18. The *phloem* conducts dissolved food to the parts of a plant.

19. Stems increase in thickness because new cells are produced in the *xylem* region of the fibrovascular bundles.

20. Most of the body of an old dicot tree consists of *wood* layers made of *living* cells.

21. The chief supporting structure in monocot stems is the *pith*.

22. The *pith rays* supplement the fibrovascular system by aiding in the movement of sap.

23. A tree grows taller and more bushy by the growth of *cambium*.

24. State as many similarities and differences as you can between monocots and dicots.

BIOLOGICAL PRINCIPLES · **1.** Because only green plants can make food, they make possible all other life.

2. Green plants make food by using water and carbon dioxide as the basic raw materials, sunlight as the source of energy, and chlorophyll as the substance which brings about the formation of sugars.

3. Water and various substances dissolved in it pass through moist plant and animal membranes.

4. The combination of oxygen with food substances in the cells of plants and animals results in the liberation of energy needed to sustain the life of the cells.

5. Energy is obtained by plants from their food when the food is oxidized; carbon dioxide and water are given off as waste products of this oxidation.

6. The plants and animals most likely to survive are the ones best adapted to secure for themselves the necessities of life.

7. Plants show a division of labor, with various parts being adapted for various functions.

8. Energy is not created or destroyed, but is changed from one form to another.

* The principle of the conservation of energy

BIOLOGICAL TERMS

**membrane	**fibrovascular bundle	**bud	**oxidation
		**chlorophyll	**photosynthesis
		**cotyledon	**respiration
		**diffusion	**sap
		**energy	**transpiration
		**osmosis	**vein

Applying and Extending What You Know

AS SCIENTISTS WORK AND THINK · 1. Several high-school students were looking at some initials that had been carved in the trunk of a tree.

"Whoever spoiled the looks of that tree with his initials must have been pretty short," said Sally. "That carving must have been done several years ago, and yet the scars are not much higher than my head."

"What do you mean?" asked Tom. "The fellow who carved that was probably taller than you, Sally. Those initials were just as high when they were carved as they are now, and they'll always be just that high."

"That can't be right," said Bill. "The tree is going to keep right on growing, isn't it? How can those initials help getting farther and farther above the ground?"

"Because this part of the tree only grows bigger around," said Sue. "It is the top of the tree that grows upward."

Then everybody spoke at once, some agreeing with Sally and Bill, and others with Sue and Tom.

"What a racket!" said Bob, laughing. "Who cares anyway? I'll live just as long and be just as happy, if it moves higher or stays where it is! Let's forget it!"

"Maybe you don't care, Bob," said Jill, "but I do. I'm going to find out."

Everybody laughed as the boys and girls walked away.

Which of the scientific attitudes (p. 571) relate to this discussion? Can you suggest how Jill might find out whether the carved initials moved higher as the tree grew?

2. Can you plan an experiment to find out whether starch is made in the green leaves of a plant when the leaves are in the sunlight? First, you need to know how to make a starch test. If, when you put a drop of tincture of iodine on a plant structure or a food substance, the structure or substance turns blue-black, you can be sure that it contains starch. (Try this test with a slice of raw potato or carrot or with a piece of bread.)

Next you need to know how to remove chlorophyll from leaves, so that when you use the starch test on them, the green of the chlorophyll will not obscure the blue of the starch, if starch is present. You can do this by boiling some of the leaves in *grain* alcohol, in a test tube. But do not boil alcohol over a flame, because it might explode. Put the leaves in the bottom of a test tube and add enough grain alcohol to cover them. Then immerse (submerge) the test tube to the depth of the alcohol in a vessel containing water that is nearly boiling. (Heat the water first; then put out the flame.) Alcohol boils at 78.4° C, or 173.1° F, and hence will boil in the hot water.

Now can you plan the whole experiment? (1) Can you think of a way to get two geranium leaves, as nearly alike as possible, one of which has been growing for at least several hours in sunshine and the other in darkness? (2) Can you then remove the chlorophyll or enough of it from both leaves? (3) Can you then test both for the presence of starch?

Carry out your experiment. Did you find the answer to the problem with which you started?

In planning this experiment you provided a control (p. 570, No. 6) and only one condition in

one leaf that was different from all the conditions in the other (No. 6). What were the control and this condition (the experimental factor)?

CONSUMER BIOLOGY · Suppose that you want to buy a shade tree. What are the relative advantages and disadvantages of a deciduous and an evergreen tree for this purpose?

APPLYING YOUR KNOWLEDGE OF BIOLOGY · 1. What must plants have, in addition to water and carbon dioxide, in order to make food? What are the sources of these other necessities?

2. Which do you think appeared first on the earth, plants or animals? Why?

3. When a shrub or tree is transplanted, it is usually removed from the soil where it has been growing, with a large ball of earth attached to the roots. Often this ball of earth is tied in place with burlap. Why is this done?

4. In some hospitals it is still customary to remove from patients' rooms, in the evening, the flowers which have been sent to them. Is there a good reason for doing this?

5. The earthworm is of great value to agriculture because of its life habits. Its burrows permit air and water to enter the soil. Its casts, which are the wastes from its digestive system, make the soil richer in nitrates. Some successful experiments have recently been conducted in raising earthworms to be put in gardens. How is this last statement related to the illustration on page 2?

6. Why do we not find a dense growth of grass on the floor of an old forest?

7. Make a list of five or more annuals and a similar number of biennials and perennials which commonly grow in your vicinity.

8. Why do plants often die if their roots are under water for several days, as during a flood?

9. Whenever trilliums, bloodroots, spring beauties, and many other kinds of wild flowers are picked, usually the leaves are picked along with the flowers. Why, therefore, do many of these plants starve to death?

EXPERIMENT · Do some common seed plants develop chlorophyll while growing in darkness or while growing in sunlight? Fill two pairs of berry boxes with soil. In each box of a pair plant the same number of seeds of wheat, oats, or corn. In each box of another pair plant the same number of grapefruit seeds. Now put one box of each pair in a dark place, and the other in a place where it will receive as much sunlight as possible. Keep the soil slightly moist in all the boxes. All the conditions in the boxes should be the same, except the presence or the absence of sunlight. After ten days or longer compare the plants growing in each pair of boxes.

Tell what the results of this experiment indicate by selecting the correct answer from the following test item: The results of this experiment indicate that seed plants develop chlorophyll while growing (1) in sunlight; (2) in darkness; (3) in either sunlight or darkness; (4) in neither sunlight nor darkness; (5) in sunlight in the case of some plants and in darkness in the case of others.

WHY NOT BECOME A NATURALIST? · 1. What can you learn about the leaves found on various kinds of plants in your neighborhood? Observe how they are arranged on the stems, how they vary in size and shape, and how the veins are arranged. In what respects do you find that leaves are all alike, and in what respects do they differ? Take notes on your observations or make sketches of them.

2. What are the characteristics of the buds on some of the plants in your neighborhood? Study the buds on the tips of the small branches; notice the arrangement of the leaf buds. Try to determine, by finding the growth joints (nodes), how much the tip of a branch has grown this year, and how much in previous years. Take careful notes as a basis for later reports.

3. What are the characteristics of annual rings? Study the ends of stumps and logs. Make sketches to show characteristics.

8

CONTROLLING THE MANUFACTURE OF FOOD

1. *What Aspects of Food Storage in Plants Are Important to the Gardener and the Farmer?*

The history of agriculture is the story of man's progress in controlling for his advantage the plants that make food and other products which he needs. He has made himself the ally of these plants in their struggle for existence. By applying his knowledge of biology, he helps the plants that are useful to him to be successful in spite of both their living enemies and unfavorable conditions in their environments. Then he takes for his own uses the food or other products that they have produced. By doing so he is able to survive more certainly and comfortably than other living things.

FOOD STORAGE AND PLANT SURVIVAL · During the hours when green plants can carry on photosynthesis, they must make more than enough food for their immediate needs, and they must store the surplus in their tissues. If they could not do both these things, they would be unable either (1) to remain alive during times when they cannot make food, as at night or during the winter, or (2) to store enough food in their seeds or other reproductive structures to enable their offspring to keep alive until the young plants could grow leaves and make their own food. The ability to manufacture and store surplus food makes possible the survival not only of the individual plant, but of its race, or kind.

THE STORAGE OF ENERGY FOODS · Biologists do not yet know exactly what chemical processes are carried on by the green-plant cells during photosynthesis. They hope, however, to find out soon by means of experiments with radio-active carbon secured through atomic research. They are now convinced that sugar is an early product. They know also that further chemical processes change part of this sugar to starch. This remains in the leaf and is used later by the plant.

The rest of the sugar is transported, as a part of the sap, through the phloem and the xylem regions of the fibrovascular bundles to all parts of the plant.

The sugars and starches are energy foods. They are so called because they provide energy needed by plants and animals for their various life activities. The energy foods include oils and fats and proteins,[1] in addition to sugars and starches (illustration, p. 171). Of these, however, only sugars dissolve readily in water. Hence most of the surplus food

[1] *Protein* (prō′tē ĭn). Some authorities do not include the proteins with the sugars, starches, oils, and fats as energy foods. In this book, however, proteins are considered to be energy foods because, in addition to their other uses, they serve as fuels, just as do sugars, starches, oils, and fats. Some authorities group the sugars, starches, oils, fats, and proteins together as *organic nutrients*.

Duraglas Containers

This Trinity grape-vine at Mission San Gabriel, California, is one of the oldest grape-vines in America. It was planted before the Revolutionary War and is still bearing. Which of the energy foods do you think is chiefly stored in the ripe grapes? Which do you think is likely to be chiefly stored in the grapes before they become ripe? Which do you think least likely to be stored in them at any stage of their development?

of plants is stored as starches, oils and fats, and proteins, though sugars are stored in considerable quantities in fruits. Whenever the plant later draws on these reserves of food, the starches are changed back into sugars, and the oils, fats, and proteins into other substances which can be dissolved in the sap and carried as part of it to the cells where food is needed.

Energy foods are changed from one form to another in plants, as is illustrated by the changes in an apple. If you eat a green apple, you find it sour. It is so because, when an apple is green, it contains considerable quantities of acids, and acids have a sour taste. If later you eat a ripe apple from the same tree, you find it much sweeter than the green apple was. The reason for this change in flavor is that as an apple becomes ripe, some of its acids are changed to sugar. A ripe apple, if kept for some time after it has been picked, loses some of its sweetness and becomes rather dry and crumbly. Some of the sugar has been changed to starch. If kept

for a considerably longer time before it is eaten, the apple becomes tough and loses a good deal of its flavor. Some of the starch has been changed into cellulose.

THE NATURE OF THE ENERGY FOODS · All energy foods are organic[1] compounds. Sugar, starch, and also cellulose belong to the class of organic compounds called carbohydrates.[2]

There are a number of kinds of sugars made by plants. These include grape sugar (glucose) and fruit sugar. Also, there are many kinds of starches, oils, fats, and proteins. Each species of plant, in fact, makes its own special kind. Plant cells make starches and oils out of sugars. They use sugar also, to start with, in building proteins. The green parts of plants can make all the energy foods. Parts without chlorophyll cannot build sugar, but only starches, oils, and proteins.

FOOD STORAGE IN VEGETABLES · From the time that a green plant begins to make its own food, it deposits the surplus in several or all of these structures: LETTUCE, CARROT, CAULIFLOWER its leaves, roots, flowers, fruits, seeds, and stem (illustration, p. 173). Practically every food plant stores mineral compounds and vitamins, in addition to energy foods, in one or more of these same structures.

We harvest each food plant when its stored food is in the condition most suitable to our use. Thus we harvest radishes and asparagus when they are fairly young, and winter squash and dry beans when the plants are mature.

DEF DEF DEF

ANNUAL, BIENNIAL, AND PERENNIAL CROP PLANTS[3] · The crops of annuals, such as bean, corn, lettuce, pea, pepper, pumpkin, and tomato, and most common grain crops, are, of course, available in the same year in which their seeds are planted. The biennial plants, such as cabbage, cauliflower, carrot, rutabaga, and turnip, are harvested during the first year of their lives. During this year they are storing the food which would enable them to live through the winter and until their new leaves could develop in the following spring. The gardener leaves only enough of them unharvested to provide the desired quantities of seeds, or, in climates cold enough for them to freeze during the winter, he takes them up in the fall, plants them where they will remain alive, and sets them out again in the garden the following spring. Such plants produce seeds only in their second year.

Perennial small fruits, such as raspberries and strawberries, and kitchen-garden plants, such as asparagus and rhubarb, produce harvests every season during their several years of life.

2. *How Can We Help Our Plant Allies in Their Struggle for Existence?*

Perhaps you grew a Victory Garden during one or more years of the Second World War. If you live in the city, perhaps your family experienced then, for the first time, the pleasure of harvesting and eating vegetables when they are freshest and hence most delicious and most valuable as food.

The grave shortage of food throughout most of the world which has existed since the end of the Second World War makes the need for home gardens in this country almost as

[1]Cultivate the habit of using the Glossary and the Index for reviewing the meanings of scientific terms.

[2]*Carbohydrate* (kär bō hī′drāt).

[3]Page 563.

The structures of various garden plants which, at the time we harvest them, contain most of the energy foods which these plants have stored · Which of these structures is not named where this illustration is cited on page 172? Why is it not named there?

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great now as it was at any time during the conflict.

THE GARDEN HABITAT · **Kinds of soils.** Soils are classified in many ways. They are grouped, for example, in accordance (1) with the kinds of crops that grow best in them, as "cotton soils" or "wheat lands"; (2) with the regions where they are found, as "the brown desert soils bordering the Rocky Mountains on the east" or "the prairie soils of the Middle West"; (3) with their origin, as determined by whether they have remained where they were formed (residual soils), or have resulted from erosion by glaciers, rivers, or winds (transported soils).

A common method of classifying farm and garden soils is based on the size of the particles that compose them. These soils, in the order of largest to smallest particles, are gravel soil, sandy soil, loam, and clay soil. Though different samples of each of these kinds vary

considerably in characteristics and value, yet they resemble one another closely enough so that they can be recognized as belonging to the same group.

Gardeners and farmers find each kind of soil fairly easy to recognize. (1) Gravel soil consists largely of small stones. Such soil is usually of little value, because it does not hold enough water for most crop plants and because it contains too little organic matter, or humus.

(2) Sandy soil is composed of either coarse or fine sand, or of a mixture of both. It is loose and contains abundant air spaces. Hence it has the advantages of being well drained and well ventilated. It is not suitable for most crops, however, because it usually is lacking in humus.

(3) Loam is composed of sand, silt, and clay in varying proportions. It is the most satisfactory of all because it drains well, it is well ventilated, it holds sufficient soil water, and it contains enough humus for most crops.

(4) Clay soil is made up of minute particles. It is lumpy when wet, and its surface is hard and compact when dry. It neither absorbs water quickly nor drains readily. Also, it is not well ventilated. It is likely, however, to contain considerable humus. Clay soils are frequently "sour," or acid,

During the Second World War aviators of the United States army dropped packets of seeds, with planting instructions such as these, to natives in territory which the Japanese had captured and still held. Do you recognize what food plants these are?

Crowell-Collier Publishing Company

United States Department of Agriculture

In Canada and the United States, land that slopes to the south warms up faster than land that slopes to the north. Explain

soils and hence will not produce good crops unless lime is added to remove the acid condition.

Different kinds of plants require different soil conditions. For example, there are vegetables and farm crops that will grow well in sandy soil and others that will thrive in clay soil. If possible, however, a garden or a farm should be located where the soil is a loam.

Temperature and crop growth. The temperature of the soil is an important factor in the growth of plants. To illustrate, the seeds of most crop plants will germinate,**[1] or sprout, only if the temperature of the soil is 60° F or higher, and few will germinate if the soil temperature falls below 40° F. If the soil is too cold for germination**[2] the seeds are likely to rot as a result of the activities of bacteria of decay in the soil. These bacteria will first consume the seed coat as food and will then consume both the embryo plant and the food stored with it inside the seed.

The soil temperature indirectly affects the growth of crops in another way: the nitrogen-fixing bacteria and other soil bacteria,[3] whose activities aid plant growth, are most active when the temperature is between 80° F and 100° F.

"Warm soils" and "cold soils." Soils are considered to be "warm soils" or "cold soils" depending on how readily they are warmed by sunshine. Dark-colored soils warm up faster than light-colored soils because dark-colored objects absorb more of the sun's rays than light-colored ones (illustration above).

Soils that drain readily, such as sandy soils and sandy loams, are warm soils. Those that

[1]*Germinate* (jûr′mĭ nāt).

[2]*Germination* (jûr mĭ nā′shŭn).

[3]Page 96.

Forsythe, from United States Department of Agriculture

Cultivating a Victory Garden · What questions does this picture suggest to you?

remain wet and undrained, as clay soil does, are cold soils. The reasons why wet soils are slow to become warm are that (1) more heat energy is necessary to raise the temperature of a pound of water one degree than to raise the temperature of a pound of soil one degree, and (2) there is more evaporation from the surface of a wet soil than from the surface of a well-drained soil, and such evaporation cools the soil.

Cold soils can usually be improved by adding sand or wood ashes, or plant stalks, stubble, or other crop refuse, to make them less compact and consequently more readily drained.

HELPING OUR PLANT ALLIES · **To secure minerals.** ᴾLike every other organism, every plant requires certain minerals,[1] from which it obtains certain necessary elements. It cannot achieve its full development if a single necessary element is lacking in the soil. Fortunately, such small amounts of most of the required elements are needed that soil usually contains enough of them. The ones most likely not to be present in sufficient amounts are the four elements which crop plants need in greatest quantities, namely, nitrogen, phosphorus, calcium, and potassium.

The scientific farmer does not leave the mineral content of his soil to chance. He has samples of the soil tested by the local farm agent or by the state or the provincial department of agriculture to determine what minerals are lacking and hence need to be added in order to grow the desired crops. It is usually not worth while, however, for a gardener to have soil tests made of his small plot. Such minerals as it may lack are likely to be supplied by the addition of fertilizers. Barnyard manure or green manure[2] furnishes

[1]Footnote 2, p. 66.

[2]Page 99.

abundant nitrates, and many of the commercial fertilizers provide compounds of phosphorus, calcium, and potassium, in addition to nitrates.

It is possible for garden soils to be made too rich in certain minerals, especially nitrates. Some diseases of vegetable plants result from too much, just as others result from too little, of certain minerals in the soil.

You can tell fairly well whether the soil of your proposed garden plot is rich enough to produce vegetables, if you observed the crop of weeds that grew on it during the previous season. The denser and ranker the crop of weeds was, the better are the chances of an abundant crop of vegetables, because weeds and crop plants are similar organisms. There are no characteristics that would enable you to tell one from the other. Any plant is a weed if it happens to be growing where we do not want it to grow. A potato plant in the middle of a flower garden would be as much a weed there as would a dandelion plant. A pansy plant growing in a row of beets would be as much a weed as any other plant that we should not want to find growing there.

As allies of our food plants, we not only put needed minerals into the soil, but also cut off, pull out, or destroy with chemicals the weeds that compete with our favored plants for the available minerals.

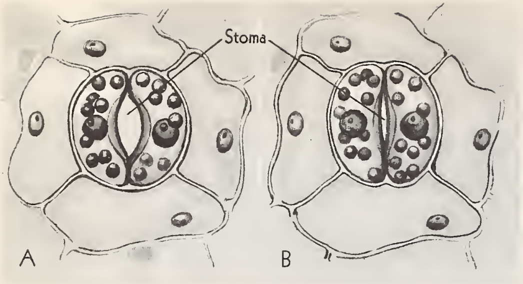
To secure water. There are millions of acres of farm land and millions of gardens located where there is scarcely enough rainfall for crop plants. Ways in which the favored plants can be helped to secure more water in such localities include (1) breaking up the soil surface, (2) removing competing plants, or weeds, and (3) irrigating.

1. *Breaking up the soil surface.* Cultivating the soil (1) provides more room for the growth of the roots of crop plants and also (2) destroys the soil capillaries, thus greatly reducing the amount of water evaporated from the surface of the ground. The finer the surface particles are made, and hence the better the mulch, the more the soil water that remains available to the plants. Sandy soils and loams are broken up easily. Clay soils are likely to be hard and to remain in clods, especially if the soil is wet when the cultivating is done.

2. *Removing competing plants.* The weeds compete with the garden plants for the soil water, as well as for the minerals. Therefore, by getting rid of the weeds, we can make more water available to the vegetables. Care must be taken lest the garden plants be injured by the way in which the weeds are removed. The weeds should not be chopped off, with a hoe or other cultivator, near enough to the vegetables to injure their roots. Furthermore, none but the little weeds should be pulled out from around the vegetables. The large weeds should be cut off above the ground with a knife, in order not to disturb the soil and thus harm the root hairs of the food plants.

Agricultural chemists have recently produced weed-killing substances which are proving to be of considerable value. The usefulness of these products, however, is relatively limited because they are not sufficiently specific—that is, fatal to certain weeds, but not to crop plants.

Garden manuals and the directions printed on seed packages give instructions to plant certain vegetables, such as beets, carrots, radishes, and lettuce, close together and to thin them out later by removing the less vigorous ones. If this were not done, the plants would not produce enough surplus food to develop the big roots or "heads" that are wanted, because there would be too much competition among them for sunlight and for the water and minerals in the soil.



Stoma open (*A*) **and closed** (*B*). The amount of transpiration is regulated, according to the needs of the plant, by the size of the stomata. It does not directly depend on the temperature, as evaporation does. **Topic for Individual Study:** How the stomates are caused to open and close. (Consult a college textbook of botany)

3. *Irrigating*. Like all other organisms, crop plants can grow and develop normally only when they have enough water. The amount of water that a plant needs to take in may be reduced either (1) because too many of its root hairs become injured or (2) because the soil becomes too dry. In such a case, water may be given off by transpiration through the stomata[1] and by evaporation from the leaf surfaces faster than the root hairs can replace it. As a result, the plant wilts. As soon as the guard cells surrounding the stomata lose some water, and hence are not completely filled, their inner walls no longer remain apart but automatically close the stomata between them (illustration above). Thus further loss of water through transpiration is stopped.

When vegetables are transplanted, many of the root hairs are likely to be injured. Also, they may dry up, even though the plants are removed with considerable soil and are protected by a wrapping of wet paper. Consequently the plants in their new locations may wilt badly or even die. Thorough watering of the soil may enable the reduced number of functioning root hairs to take in enough water to restore the plants. Also, removing some of the leaves and shading the plants with shingles or berry boxes may restore the plants by reducing the amount of transpiration and evaporation from their surfaces until they have had time to become well established in the new habitat.

[1]Page 153.

It is better to give the garden a plentiful soaking once a week than to sprinkle it for a short time every day. The alternate thorough wetting and drying of the soil tends to loosen it. Also, deep soaking tends to encourage the growth of deep roots rather than surface roots. The deeper roots give the plant a better chance to survive because (1) they are less likely to dry out, and (2) they are better able to secure soil water.

To secure sunlight. Garden plants must have abundant sunshine in order to make surplus food. For most crops, therefore, the garden plot should be located where the plants will have direct sunshine for at least three or four hours in the middle of the day, and longer if possible.

You have probably observed that vegetables do not grow well near a tree, or that the part of a farm crop on the edge of the field near a wood lot does not develop well. There is a reason for this, besides the fact that the trees take, from the soil, water and minerals that the crop plants need. The reason is that, by shading the crop plants, the trees cause them partly or wholly to starve.

In planning a garden, not only should we locate the plants well away from trees, but also we should make sure that tall crops, such as corn or pole beans, are not placed where they will shade low-growing vegetables. Also, wherever possible, we should make the rows run north and south, rather than east

and west, so that the plants in the rows will shade one another as little as possible. Removing the weeds is still another means of making more sunlight strike the garden plants.

TIMES OF PLANTING · Like farm crops, garden vegetables cannot all be planted at the same time, because different plants need different conditions in order to survive. For example, such plants as early potatoes, onions, lettuce, turnips, and asparagus are able to withstand fairly cold weather. Hence they can be planted as soon as the ground can be worked in the spring. Such plants as carrots, sweet corn, and bush beans should not be planted until the danger of frost is past. Another group, including tomatoes, eggplant, cucumbers, squash, and melons, will not thrive out of doors until the soil has become warm.

Hence, in order that plants which must not be planted outdoors early may nevertheless get an early start, or in order to enable them to produce their crops in northern localities where the growing season is short, it is necessary to start them indoors early in flats. A flat is a shallow box or tray filled with rich soil. The seeds are sown thickly in it. They will have developed into good-sized plants by the time the weather is warm enough for them to be transplanted to the garden.

Soldiers of the Second World War picking vegetables in their soil-less garden on Ascension island, a rocky island in the Atlantic Ocean · Soil-less gardens will continue to be useful in localities where ordinary gardening cannot be carried on. It is not likely, however, that gardening without soil will ever be an important source of vegetables. Why?

United States Army Air Forces

VARYING THE GARDEN HABITAT · **By supplying light and carbon dioxide.** It has been learned from experiments that plants will carry on photosynthesis with strong artificial light. Under such conditions certain vegetable crops have been produced in less than the normal length of time because the plants were able to make food constantly and did not need to draw on their stored reserves at night. It has been learned also from experiments that some crops can be made to mature faster by increasing the proportion of carbon dioxide in the air around their leaves. This is sometimes done by releasing from pipes, running between plant rows, carbon dioxide obtained from waste gases from factory chimneys.

By eliminating the soil.[1] At least half a century ago it was discovered that common garden plants can grow without soil, provided that their roots can secure the water and minerals they need. This knowledge was of great value during the Second World War, for it enabled small groups of our armed forces in several of the desert and volcanic islands to be supplied with fresh vegetables which could have been furnished them in no other way (illustration, p. 179).

In this type of gardening, vegetables are commonly grown in tanks four feet wide by eleven feet long. These tanks are filled with water in which exactly the right kinds and quantities of minerals have been dissolved to supply the needs of the particular plants that are to be raised. Wire netting is stretched over the tops of the tanks. Sawdust or excelsior is spread over the netting, and the seeds are planted in this covering. The covering is kept wet with the solution, with the result that the seeds soon germinate and the roots of the young plants grow down into the solution.

Excellent crops of tomatoes, beans, peas, carrots, and other vegetables can be grown in this way. Moreover, several kinds of crops can be grown at the same time in the same tank, and as many as three crops of the same vegetable can be grown in a year.

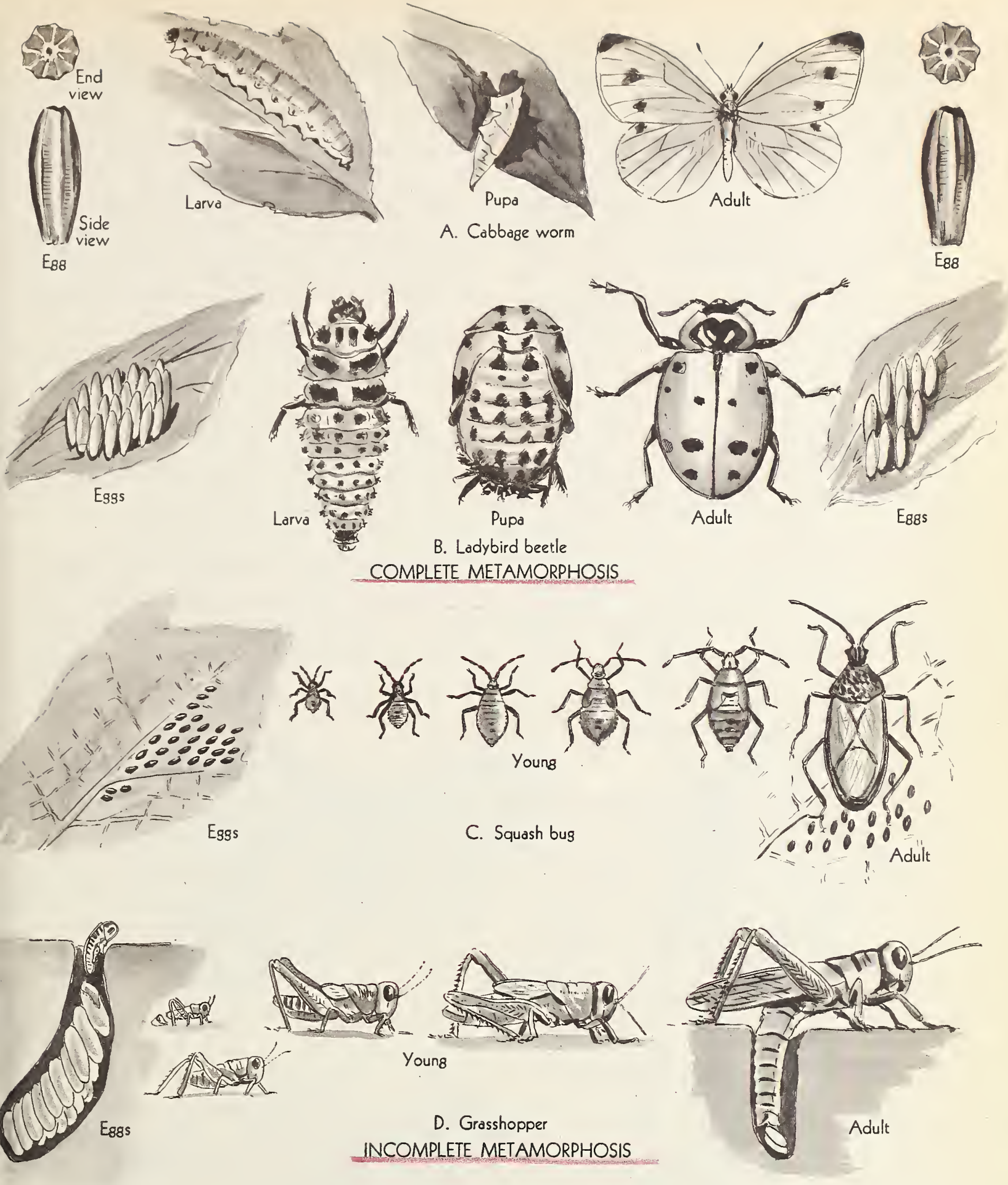
Experts trained in methods of making soil-less gardens were sent to islands in the Atlantic and South Pacific soon after these had been captured from the Axis enemies. Also, they have been sent to New Zealand, New Guinea, and India. Within less than a year after the surrender of Japan, the American army of occupation had begun the construction of soil-less gardens covering an area of eighty acres. It is expected that soil-less gardening will be especially useful in certain places where soil gardens are not possible.

3. *How Can We Defend Our Food Crops?*

Helping the domesticated plants to secure the necessities of life, in the ways described in the preceding section, is one important task of the farmer and gardener. Making available to the plants more minerals, water, and sunshine, and killing the weeds that would compete with them for these essentials, increase greatly the farmer's chances of obtaining the desired crops. But an equally important and an even more difficult task remains to be done. That task is to defend the plants against organisms besides ourselves that seek to use them as food.

ENEMIES OF CROP PLANTS · From the time that the seeds germinate until the plants complete their life cycles, they are certain to be attacked by numerous enemies. These

[1]The science of growing plants without soil is called *hydroponics* (hī drō pŏn′ĭks).



The stages in the life cycle of *A*, *B*, two insects that develop through a typical complete metamorphosis; and of *C*, *D*, two insects that develop through a typical incomplete metamorphosis. In which of the two types of metamorphosis does the young insect develop through a greater number of stages?

enemies include (1) arthropods,[1] chiefly insects, together with some spiders, millepedes, and sow bugs; (2) some fungi[2]; and (3) a few roundworms,[3] slugs,[4] and other kinds of living things. If the attacks of these enemies kill the food plants or spoil their products for our use, our survival is made more difficult and could become impossible.

LIFE HISTORIES OF INSECTS · **Complete metamorphosis.** [E]It is necessary to know how typical insects develop in order to understand how they attack garden plants and how they may be combated. Many insects, such as moths, butterflies, beetles, bees, and flies, pass through four stages in their life histories. These stages are (1) egg, (2) larva, (3) pupa, and (4) adult (illustration, p. 181). Such insects are said to pass through a complete metamorphosis.**[5] The young insect hatches from the egg as a larva. In this stage it looks like a worm.[6] Larvae are of various forms, sizes, and colors. Some are without legs, and others have from three to eight or more pairs of leg-like organs.

[E]Larvae are active and grow rapidly. Hence they need large quantities of food. After a time the larva builds around itself a hard case, a cocoon, or other protective covering, and enters a resting stage. It is then a pupa.**[7] While in this stage, it changes in structure, and, when sufficiently mature, bursts out of the pupa case as an adult. It rapidly completes its development and mates. The life cycle begins again when the females lay their eggs.

[1]Page 527. [2]Page 557.
[3]Page 519. [4]Page 524.
[5]*Metamorphosis* (mĕt *ȧ* môr′fō sĭs): one of the marked and more or less abrupt changes in structures and habits of an animal in developing from the egg to the mature, or adult, stage. Consult the Index to locate an illustration showing the *metamorphoses* (mĕt *ȧ* môr′fō sēz) of several other kinds of invertebrates beside insects.
[6]Page 519. [7]*Pupa* (pū′p*ȧ*); plural, *pupae* (pū′pē).

Incomplete metamorphosis. [E]Some insects, such as grasshoppers, squash bugs, aphids,[8] crickets, walking sticks, and cockroaches, pass through only two, instead of four, *distinct* stages of development (illustration, p. 181). They are never larvae or pupae. Such insects are said to pass through an incomplete, or gradual, metamorphosis. When one of them hatches from the egg, the young insect is called a nymph.**[9]

A nymph resembles an adult in much the same way that a human baby resembles a man or a woman, that is, by having a larger head in proportion to the rest of its body than an adult has, and by having incompletely developed legs and other structures. At the start, moreover, a nymph lacks wings.

The nymph grows rapidly until its skin becomes tight. Then it molts, or sheds its skin. It repeats this process several times. After each molt the young insect resembles the adult more closely than before. After the final one it reaches maturity and soon mates.

[E]Insects that have complete metamorphoses are dangerous to plants either while they are larvae or while they are adults, or, in some cases, during both these stages. Insects that have incomplete metamorphoses are always dangerous to plants, from the time the young hatch from the eggs.

Insect enemies of food plants. The insect enemies of our cultivated plants may be conveniently grouped in accordance with the ways in which they injure the plants. Thus there are (1) the chewing insects, such as the Japanese beetle, the cotton boll-weevil, the European corn-borer, and the sweet-potato weevil (illustration p. 183), and (2) the sucking insects, such as the aphid, the chinch bug, the scale insects, and the squash bug. Some in each group feed upon the leaves, stems,

[8]*Aphid* (ā′fĭd). [9]*Nymph* (nĭmf).

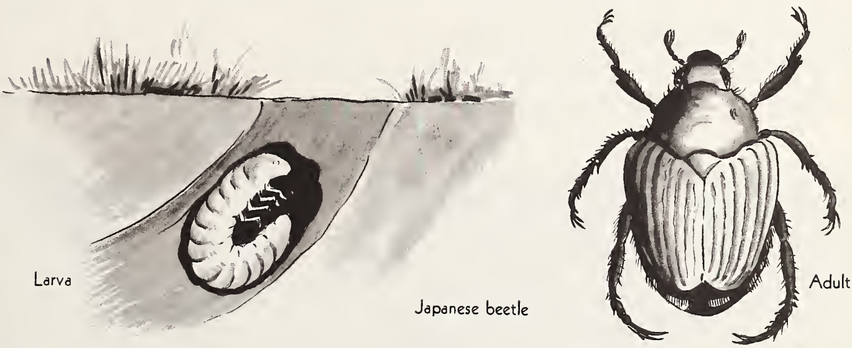
flowers, fruits, or roots of the plants. Others get inside the plants and consume them from within.

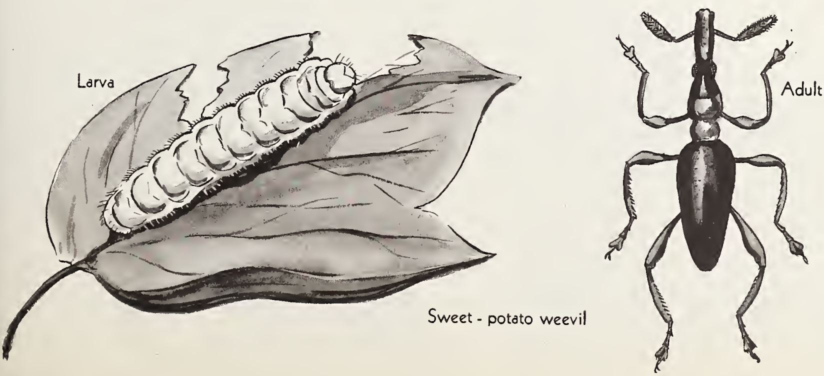
The chewing insects that attack a plant from the outside leave wounds in the plant. Disease germs may enter through these wounds. Also, the plant may be weakened by loss of sap, just as an animal may be weakened by bleeding.

The chewing insects that feed upon the internal structures of a plant gain entrance usually in one of two ways: (1) In some species the females thrust their egg-laying organs (ovipositors[1]) into the tissues of the plant and lay their eggs there. The larvae begin their lives inside the plant and usually eat their way out when they are ready to become pupae. (2) In other species the larvae are hatched from eggs laid on the leaves or other plant structures or in the soil. These larvae eat their way into the plant soon after they

[1]*Ovipositor* (ō vĭ pŏz'ĭ tẽr).

The Japanese beetle is a "general feeder"; that is, it feeds on almost any kind of green plant. As a garden pest, its larvae feed on the roots of bean, tomato, beet, sweet corn, onion, strawberry, and other vegetable and fruit-bearing plants. The adult beetles eat the leaves of beans, asparagus, rhubarb, and corn—also the corn silk. The sweet-potato weevil is a "specific feeder" because its larvae can eat almost no domestic plants except sweet-potato and morning-glory vines. Which of these pests is likely to be the more serious? Why? Which has the better chances for survival? Why? Can you be sure?





hatch from the eggs. Like those in the preceding group, they emerge (come out) when ready to become pupae. The young insects of both groups secure from the plant not only food, but also shelter and protection from insect-eating birds and other animals that might prey upon them.

As a result of attacks from such insects, the plants wither, or their stalks break and fall over. Even though they do not die, they are not likely to produce the desired crops. The "wormy" fruits of apple, peach, and other orchard trees frequently drop off the trees before they mature.

Some sucking insects pierce the plants in various parts and suck the sap from the fibrovascular bundles. Others wound the leaves or other structures and ingest[1] the sap that "bleeds" from the wounds. Even though the plants do not die from such attacks, their leaves curl, their stems wither, or their fruits fall or become deformed.

They live on a host

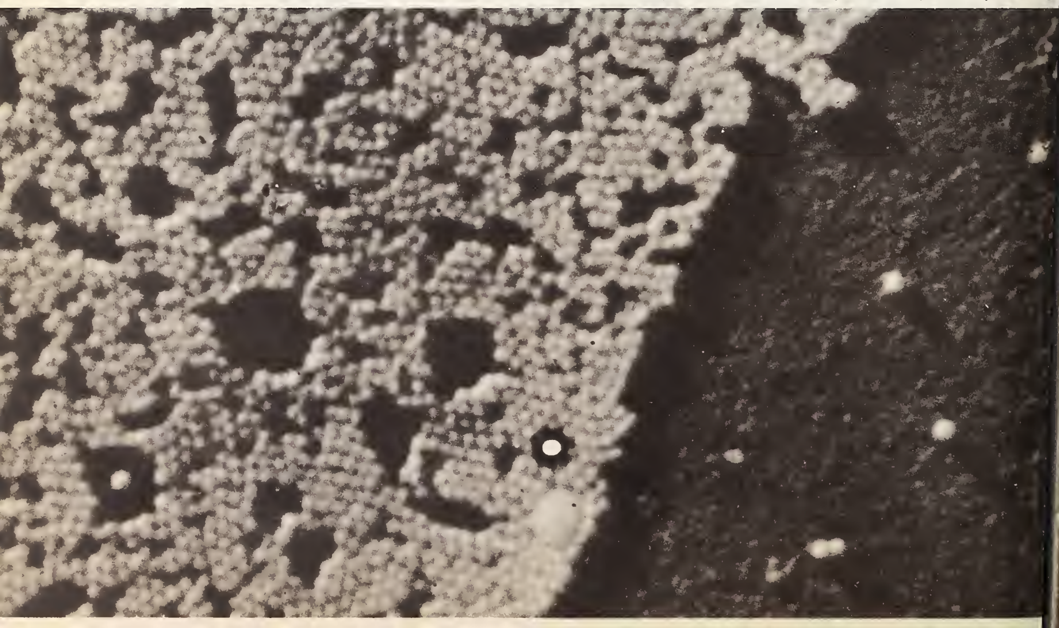
DISEASES OF GARDEN PLANTS · **Parasitic diseases.** Germ diseases are common among domesticated plants. Few of our vegetables are free from attacks by disease-causing parasites of one sort or another. Most of the parasites are fungi,[2] such as bacteria, rusts, blights, mildews, and smuts. They produce a variety of diseases, commonly called rots, leaf spots, wilts, blights, drops, and damping-off. Other disease-producing parasites, besides these fungi, include slime[3] molds, which cause clubroot in members of the cabbage family, and roundworms, which produce root knot in several vegetables.

[1]*Ingest* (ĭn jĕst′): to eat or take in food. *Ingestion** (ĭn jĕs′chŭn): the act or process of taking in food.

[2]Page 557. [3]Page 565.

Giant protein molecules of the bushy-stunt virus of the tomato plant, magnified 80,000 times · This is a "shadow cast" photograph, taken with an electron microscope (illustration, p. 404). **Topic for Individual Study:** Virus diseases of garden plants. (Consult bulletins from your state or provincial department of agriculture)

Ralph W. G. Wyckoff and Robley C. Williams, University of Michiga



Non-parasitic diseases. A few plant diseases are due not to parasites, but to unfavorable conditions related to the temperature of the soil and to the amount of moisture and of minerals in it. Still other diseases, such as some "yellows," and the "mosaic diseases," so called because the infected[1] parts of the plants are covered with different-colored patches or spots, are caused by viruses.[2]

Virus diseases are common among animals, including man[3] and probably are still more common among plants. Even bacteria sometimes have virus diseases.

ERelatively little is yet known about viruses. Scientific evidence indicates that a virus is not a living organism and hence could not be a true parasite. It may be a "border-line" body, that is, one that is intermediate between the most highly organized non-living bodies, the crystals, and the simplest living things, the one-celled organisms. Scientists believe that a virus is a protein body consisting, in some cases, of a single large molecule and, in others, of a few molecules (illustration, p. 184). Yet viruses act like parasites: (1) they are specific; that is, each one attacks only certain plants or animals; (2) their attacks cause their hosts to become sick; and (3) they grow and multiply, as do all living things. They differ, however, from bacteria that are not disease germs in one respect, namely, that they will grow and multiply only inside the cells of living organisms.

METHODS OF ATTACK BY DISEASE GERMS OF PLANTS · Many plant diseases are to a considerable extent general; that is, the parasites that cause them attack many different kinds of plants. Others are specific. Different disease-producing parasites attack different parts of their victims, such as leaves, stems, or roots. Most of them injure their hosts by consuming the latter's tissues. Exceptions are certain bacteria and other fungus parasites which attack cabbages, melons, and their relatives among the garden plants. They live in the xylem of the roots and use the sap of the plant as food. As they grow, they gradually stop up the xylem tubes and thus shut off the flow of sap to the upper parts of the host plant. Consequently the latter wilts and soon dies. N.B.

METHODS OF SPREADING · Plants are infected with germs of disease in ways such as these: (1) Some germs enter the roots from the soil. (2) Many are carried to the plant on the feet, wings, and bodies of insects. (3) Some stick to the clothing of the gardener or farmer when he brushes against infected plants in wet weather, and are carried by him to healthy plants.

4. Wind 5. Birds

GENERAL METHODS OF PEST CONTROL · Special bulletins on garden and farm pests can readily be secured from the Department of Agriculture of the United States or of the Dominion of Canada, from the various state and provincial departments of agriculture, and from agricultural colleges. These describe in detail the injuries and diseases of all the common crop plants. Also, they give complete directions for dealing with the predators, the parasites, or the conditions that cause the diseases. Some of the more common methods of reducing the dangers from garden and other crop pests are these:

1. Using poisons. Insect enemies are fought chiefly with insecticides.[4] The kind of insecticide used in each case depends on

[1] *Infect* (ĭn fĕkt′): to cause illness by introducing disease germs into a plant or an animal. *Infection*** (ĭn fĕk′shŭn): a disease caused by a germ transmitted directly or indirectly from a sick plant or animal to a well one. *Infectious* (ĭn fĕk′shŭs): causing, or due to, infection.

[2] *Virus* (vī′rŭs).

[3] Page 285.

[4] *Insecticide* (ĭn sĕk′tĭ sīd): a substance that kills insects.

the feeding habits of the insect to be destroyed. Among the chewing insects, those that bite out and swallow pieces of leaves and other plant structures can be poisoned with certain substances which are sprayed on the plants (illustration, p. 187). Among the sucking insects, only the ones that pierce the plant and suck up the sap that flows out of the wounds they have made can be killed with poisons. Poison for such insects is also sprayed over the plants and remains in little drops, which the insects ingest as they would sap.

Neither the chewing nor the sucking insects that get their food from within a plant can be harmed by either of the methods just described. Such insects are killed by contact poisons in the form of powders that are dusted on the plants or of liquids that are sprayed in minute drops into the air. Some insects are killed if these substances get on their bodies. Others are killed only if they breathe in the poisonous dust or the tiny poisonous drops.

Baits made by mixing moist bran with suitable poisonous substances are effective in killing such arthropods[1] as millepedes and sow bugs, as well as a number of insects, including grasshoppers, crickets, and various kinds of cutworms (the larvae of moths). The baits are scattered lightly and evenly on the ground around the plants, between plant rows, and along the edges of the garden.

Some substances that are poisonous to insects are poisonous also to human beings. Therefore the directions for preparing and using them should be followed exactly.

DDT. DDT is a powder containing a complex chemical compound made from alcohol, chlorine, and sulfuric acid.[2] It was invented by a Strasbourg chemist, Zeidler,[3] about eighty years ago, but its values did not become widely known until 1939. In that year the Swiss potato crop was being destroyed by potato beetles, which had in some way been brought into Switzerland from the United States. A Swiss chemical firm made and sold the powder, which promptly killed the beetles and saved the potato crop. The chemical firm therefore continued to experiment with the substance and finally produced it in almost its present form.

Along with its great values, however, DDT has some disadvantages: (1) Though it kills many kinds of plant pests, it does not affect some others, such as spiders. (2) It kills many useful kinds of insects quite as readily as it does harmful ones. (3) It might destroy enough of the insects that birds depend on for food, so that insect-eating birds would be exterminated in the locality where it was used. (4) It is to some extent poisonous to people when it is not properly used.

Agricultural chemists have already produced substances closely related chemically to DDT, but superior to it. Not only do these newer insecticides kill certain pests, but they do not harm the insects and their relatives whose life habits are of value to us.

2. Introducing enemies of our plant enemies. Most insects secure their food by preying upon other insects (illustration, p. 188). Many other organisms also attack insects. Hence the departments of agriculture hunt throughout the world for insects and other organisms that will attack crop pests. How such scientific warfare is carried on is illustrated by attempts to find natural enemies of the Japanese beetle. By an unfortunate chance this insect was brought into the United States some years ago along with ex-

[1]Page 527.

[2]The letters *DDT* are used for convenience in place of the name of the compound, dichlorodiphenyltrichloroethane.

[3]*Zeidler* (tsīt′lẽr).

E. I. Du Pont de Nemours and Company

Conducting modern warfare against insect pests · What questions come to your mind when you look at this picture?

ports from the Orient. Finding the new habitat suitable to it and free from its worst enemies, it multiplied rapidly. Soon it became a major crop pest in a number of states.

Recently scientists in the United States Department of Agriculture discovered that one kind of roundworm,[1] native to Japan, but not to North America, is an effective parasite of the Japanese beetle. They secured some of these roundworms and have grown them in great numbers. When the worms reach the proper stage to become parasites of the beetle, they are spread over the soil where the beetles are numerous. It is as yet too early to know how effective the use of these roundworms will be, but it is certain that they will reduce the population of Japanese beetles.

Two insects, a species of wasp and another of fly, were recently discovered also to be parasites of the Japanese beetle. Consequently they have been imported, likewise, from Japan, to reduce the population of Japanese beetles.

3. Rotating crops. Many insect and fungus pests of our garden plants can exist through the winter in the soil. If plants of kinds that they attacked one season are planted in the same soil the following year, the damage done by these enemies will be greater the second year than the first. One way of preventing

[1]Page 522.

George A. Smith

The mantis is a valuable predator of insect pests. Cases of mantis eggs, as big as walnuts, can now be bought to hang on bushes near gardens. How does this use of the mantis relate to the illustration on page 2?

such losses is to plant the different vegetables in different parts of the garden, or different crops in different fields, each year. Since many pests will attack closely related plants (for example, cabbage, cauliflower, and broccoli), members of the same family should not be planted in the same plots in successive seasons.

4. **Preventing and treating plant diseases.** Germs of plant diseases are often on seeds after the latter have been harvested. The germs remain alive and the following season attack the young plants that grow from the seeds. Some, though not all, of these germs can be killed by treating the seeds with certain germicides[1] before planting them.

Recently methods similar to those used in treating human diseases[2] have been used with success in treating certain plant diseases (illustration, p. 192).

5. **Developing disease-resistant strains.** Growers have developed certain strains, or varieties, of many common crop plants that are able to resist various diseases better than other strains can.[3]

6. **Burning diseased plants.** Many insect and fungus pests that attack crop plants can live through the winter in the plants or in parts of them that remain after harvest. No diseased plants should be plowed into the soil for humus. Instead all infected parts, including roots, should be collected and burned as soon as possible after all that is worth saving has been harvested.

Checking What You Know

BIOLOGICAL FACTS · (*Do not write in this book.*) **Pages 170–172.** 1. *Starch* is produced in the leaves of green plants before *sugar* is made there.

2. The only kind of energy food that readily dissolves in plant sap and that can be carried to all parts of the plant is (1) cellulose; (2) protein; (3) fat; (4) starch; (5) oil.

3. *Carbohydrates*, *oils*, and *vitamins* are a source of energy for plants.

4. Plants use the elements __?__, __?__, and __?__ in making carbohydrates.

5. The energy foods which furnish the material for building protoplasm are (1) starches; (2) sugars; (3) cellulose; (4) proteins; (5) fats.

6. Plants which produce seeds only in the second year of their lives are *perennial* plants, which live *several* years.

[1]*Germicide* (jûr′mĭ sīd): germ-killing substance
[2]Page 322. [3]Page 492.

Pages 172–180. **7.** State three ways in which soils are classified.

8. State two or more facts about each of four kinds of soil.

9. State two reasons why wet soils become warm slowly.

10. Name four elements which plants need, but which garden and farm soils are most likely to lack.

11. An example of a weed is (1) a dandelion plant eaten as greens; (2) any dandelion plant; (3) a dandelion blooming by the roadside; (4) a dandelion plant in the lawn; (5) a dead dandelion plant.

12. The higher plants secure most of the oxygen that they need through (1) lenticels in young bark; (2) the root hairs; (3) the petals of the flowers; (4) the large roots; (5) the stomates of the leaves.

13. Plants can live without soil if their roots are in water containing the right quantities of needed __?__.

14. State and briefly explain four ways in which man helps his crop plants to survive.

15. The *more* widely open the stomata in a plant's leaves, the *greater* is the amount of water lost from the plant.

Pages 180–188. **16.** Name and briefly describe the stages in the complete metamorphosis of insects.

17. Name and briefly describe the stages in the incomplete metamorphosis of insects.

18. A virus is like a bacterial parasite in what three ways?

19. A disease that attacks only tomato plants is a *general* disease.

20. State three ways in which disease germs are spread to plants.

21. DDT kills (1) all insects; (2) only insects harmful to man; (3) both harmful and useful insects; (4) no animals except insects; (5) no insects.

22. State six ways of protecting crop plants against insect pests.

BIOLOGICAL PRINCIPLES · **1.** Green plants obtain energy and material for growth from foods which they make by combining certain chemical elements.

2. Many living things prey upon other living things.

3. Many plants and animals exist as parasites, within or upon other living things.

4. All living things must secure energy in the form of food.

5. Food, oxygen, and certain favorable conditions of moisture, temperature, and light are essential to the life of most living things.

6. All plants and animals are engaged in a constant struggle for energy.

7. Energy and matter are not created or destroyed, but are passed on from organism to organism in endless succession.

BIOLOGICAL TERMS

**carbohydrate	**larva
**germ	**metamorphosis
**germinate	**nymph
**germination	**pupa

Applying and Extending What You Know

AS SCIENTISTS WORK AND THINK · **1.** On page 176 are these statements: "The scientific farmer does not leave the mineral content of his soil to chance. He has samples of the soil tested by the local farm agent or by the state or the provincial department of agriculture to determine what minerals are lacking and hence need to be added in order to grow the desired crops." What scientific attitudes (p. 571) does such a farmer have?

2. On page 175 you will find the statement "Different kinds of plants require different soil conditions. . . ." Plan an experiment, using the elements of scientific method (p. 570), to find out which kind of soil is best for growing some crop such as potatoes, corn, cotton, or tomatoes.

CONSUMER BIOLOGY · 1. When is the best time to buy harvested apples? Explain.

2. When buying tomato or other garden plants to transplant in your garden, why should you get and plant them as soon as possible after they have been removed from their original habitat?

3. State at least two reasons why it is of value to the consumer of fruits and vegetables to know how the enemies of food plants develop and live.

APPLYING YOUR KNOWLEDGE OF BIOLOGY · 1. Where do annual plants store most of their food? Of what value to these kinds of plants is this life habit?

2. How many examples of man's attempts to control living things for his advantage can you find in this chapter?

3. Potato plants make sugar. How do you account for the fact that white potatoes are not sweet? How do you account for the sweetness of sweet potatoes?

4. In which kind of soil would plants suffer soonest during a drought?

5. Some commercial gardeners have farms on which there may be a great deal of black, light soil known as muck, which is mostly humus. Such soil is naturally wet, and consequently must be drained. Yet often irrigation systems are also used in muck soil. Why should a gardener find it necessary both to drain and to irrigate the same field?

6. Under what conditions would it be better not to plant crops in rows running north and south?

7. Plants with soft stems wilt in dry weather. Trees do not. Explain why this is so.

8. It is estimated that weeds alone rob farmers of the United States of at least three billion dollars per year. How do you think weeds do this?

TOPICS FOR INDIVIDUAL STUDY · 1. In a reference book such as Carleton Ellis and M. W. Swaney's *Soilless Growth of Plants* (Reinhold Publishing Corporation), look up the methods used in soil-less gardening. Make a report to your class on these methods.

2. Make a study of common farm and garden pests and how to combat them. Send to your state or provincial agricultural college for information.

3. In an encyclopedia or some other source, look up the various uses of plant oils, such as soybean oil, linseed oil, tung oil, peanut oil, and olive oil.

4. The metamorphosis of a dragon-fly includes three stages. What are they? Consult a textbook of entomology or an encyclopedia. A description or labeled sketches of these stages would make an interesting bulletin-board display.

EXPERIMENTS · 1. How effective is DDT or some other, similar insecticide? Remove the top from each of two cigar boxes, and replace it with a wire screen of fine mesh. Using a small spray gun of the kind commonly used for spraying insecticides, spray the screen and interior of one of the boxes with the insecticide. (*Caution: Be very careful not to get DDT on your hands or your clothing, or on those of others. Also, be sure that nobody breathes the spray.*)

Obtain a number of each of several kinds of insects. Put equal numbers of each kind into the sprayed box and the unsprayed box. Leave the insects in the boxes until the next day. What results do you observe? Make sure that the insects in either box that appear dead are really dead. What was the purpose of the second box? Which of the elements of the scientific method (p. 570) does it represent?

2. What are the effects upon a geranium plant of adding needed minerals to the soil? Obtain two potted geraniums which are as nearly alike as possible. Mark the two pots so that you can tell them apart. In a gallon of water dissolve two tablespoonfuls of fertilizer, such as is sold in small packages in hardware stores. Each time the plants need watering, use ordinary water for one and the water containing dissolved fertilizer for the other. What differences, if any, are there in the two plants at the end of two weeks? at the end of a month? How do you account for these differences? What conclusions do you draw from the experiment? Which plant served as a control (p. 571) in this experiment? Explain. The fertilizer was the experimental factor. Explain.

COMMUNITY APPLICATION OF BIOLOGY · *Investigating the kinds of crops grown in your vicinity.* What are these crops? In what kinds of soils are they planted? How are they protected against diseases and insects? Can they withstand frost, or must they be planted after all danger of frost is over? What other factors affecting crops, discussed in this chapter, would it be appropriate for you to learn about in connection with the crops grown in your vicinity?

Extend this study with information secured from your state or provincial department of agriculture.

PROJECTS · **1. To plan and make a garden.** If you have space available, start a garden. First, make a plan of the space. Decide which kinds of plants you wish to grow, and where they are to be in the garden. Find out how they should be planted, how far apart the rows should be, and how far apart the plants should be in each row. When the proper time comes, prepare the soil and start your garden.

2. To make and use a set of boxes, known as flats, for growing plants such as tomato, cabbage, cauliflower, and pepper, to be set out in the garden. Use light wood, such as pine. Make the boxes about thirty inches long, twenty-four inches wide, and four inches deep. Fill them with rich top-soil. At the proper time sow one kind of plant seeds in each box. Apply what you have learned about the best care to give the young plants, so that they will be ready for transplanting when needed.

3. To make a display of different kinds of farm and garden soils found in your locality. Collect, in fruit jars, samples of as many distinctly different kinds of soil as you can find. Label each jar, stating what kind of soil is in it, what crops grow especially well in that kind of soil, and where the sample of the soil was obtained.

PANEL DISCUSSION[1] · Topic: How can this country make more food available to other countries that need it?

[1]Page 116.

American Cyanamid Company

A bee on a flower · If DDT were used extensively on farms, in orchards, and in gardens, it might destroy so many bees and other insects that pollinate flowers that most of the food plants would not bear fruits. How would this situation affect people living in the country? in the city?

Press Associatio

Injecting penicillin into a cactus plant to help it to recover from rot, a fungus disease · What values do you think might result from performing such experiments as this?

Millions of human beings have never had enough to eat. In some countries most of the people, at least the poorer ones, are in a constant state of semi-starvation. Great benefits would result if enough food were grown for everyone. The members of the panel might discuss these and other questions: (1) What can the scientist do to increase the world's food supply? (2) How can the farmer increase his production of food? (3) What can the governments of the various nations do to make food available to those who do not have enough? (4) How can high-school students help in making more food available to those who need it?

After the panel speakers have finished, the class may discuss which of the various plans suggested by the speakers seem good, and which do not.

BIOLOGY IN THE NEWS · **1.** In the newspapers and the magazines that you read, look for articles concerning new kinds of insecticides. Make notes of the important points in such articles, and from these notes prepare a report to be given before your class, home room, or science club. Post the articles on your bulletin board.

2. Following the directions given in the preceding paragraph, look for articles about chemical weed-killers which kill certain weeds when sprayed on them.

BOOKS FOR REFERENCE

Jaques, H. E. *Plants We Eat and Wear.* H. E. Jaques, Iowa City, Iowa.

Osterhout, W. J. V. *Experiments with Plants.* The Macmillan Company.

Rickett, H. W. *Green Earth—An Invitation to Botany.* Jaques Cattell Press, Lancaster, Pennsylvania.

BOOKS FOR LEISURE READING

Holt, Rackham. *George Washington Carver.* Doubleday Company, Inc.

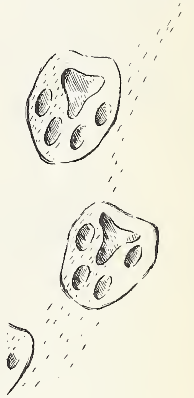
Lucas, Jannette, and Carter, Helene. *Indian Harvest.* J. B. Lippincott Company.

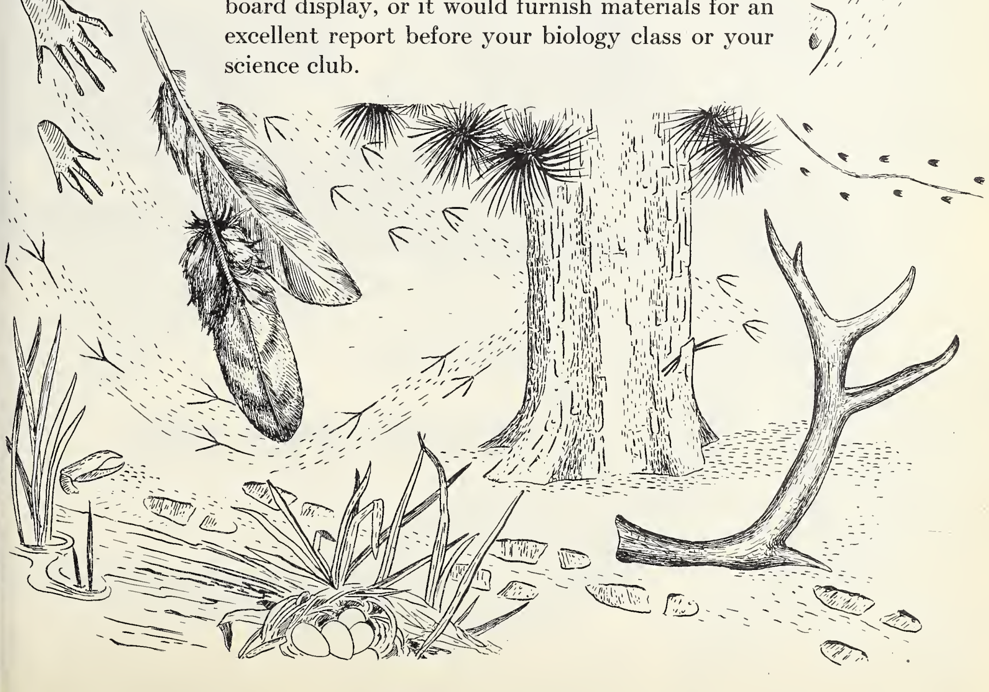
Mangham, Sidney. *Earth's Green Mantle.* The Macmillan Company.

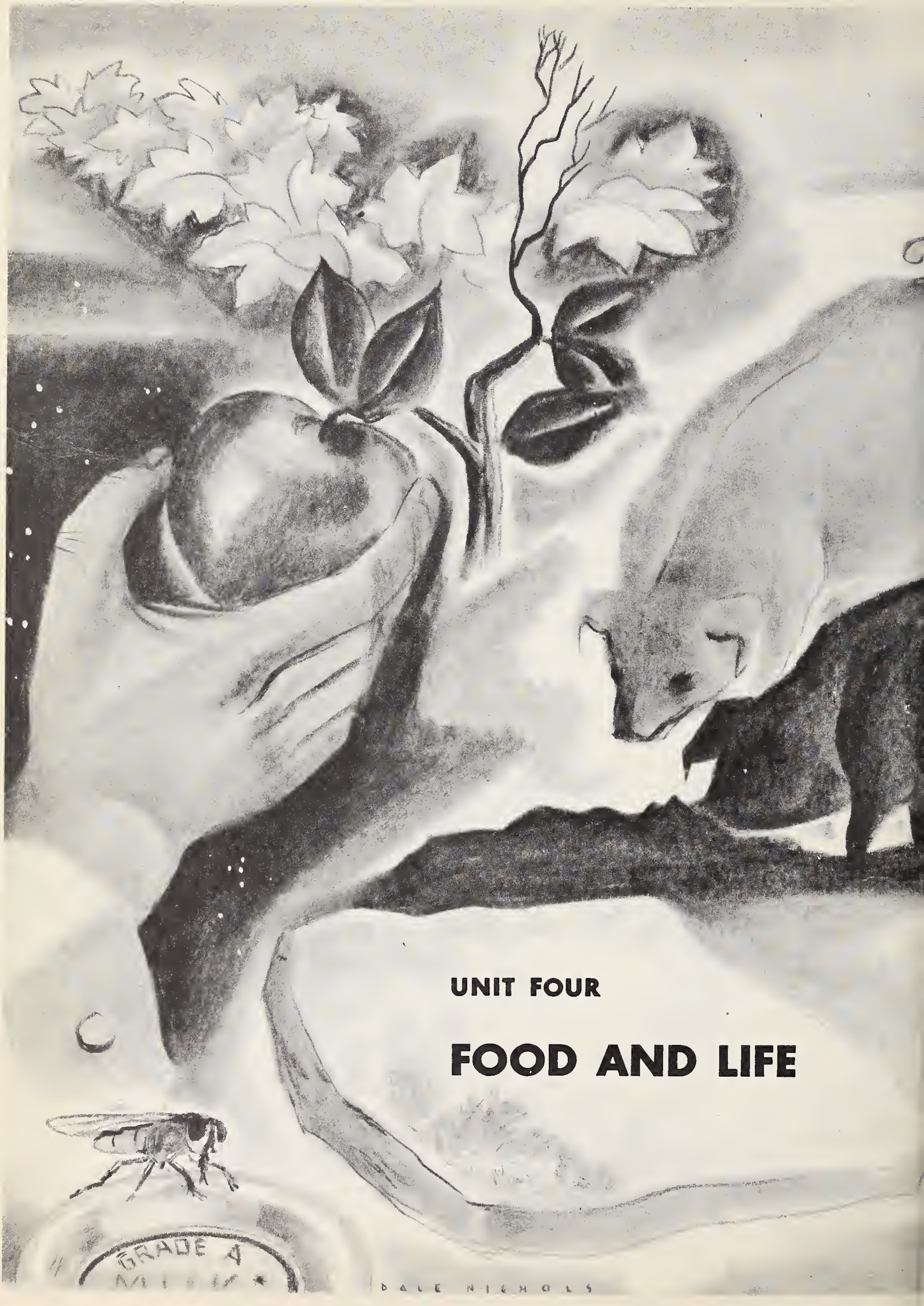
SIGNS

THE INDIANS and the early pioneers were experts at "reading signs." They had to be, in order to survive. They had to be able to tell what animals were or had been about in the vicinity, without seeing the animals. Hence they were quick to observe and skillful in interpreting such "signs" as tracks in the snow, dust, or mud; scratches on the trunk of a tree; an abandoned nest or den; broken twigs and branches; and a few hairs or a feather.

The drawings on this page are sketches of "signs." If you will form the habit of looking for such "signs" in parks, in the woods, along the roads, and almost anywhere else you may happen to be, you will find many of them. Make sketches of them and try by observation to identify the animal that made each. A selection of such sketches would make an unusual and interesting bulletin-board display, or it would furnish materials for an excellent report before your biology class or your science club.

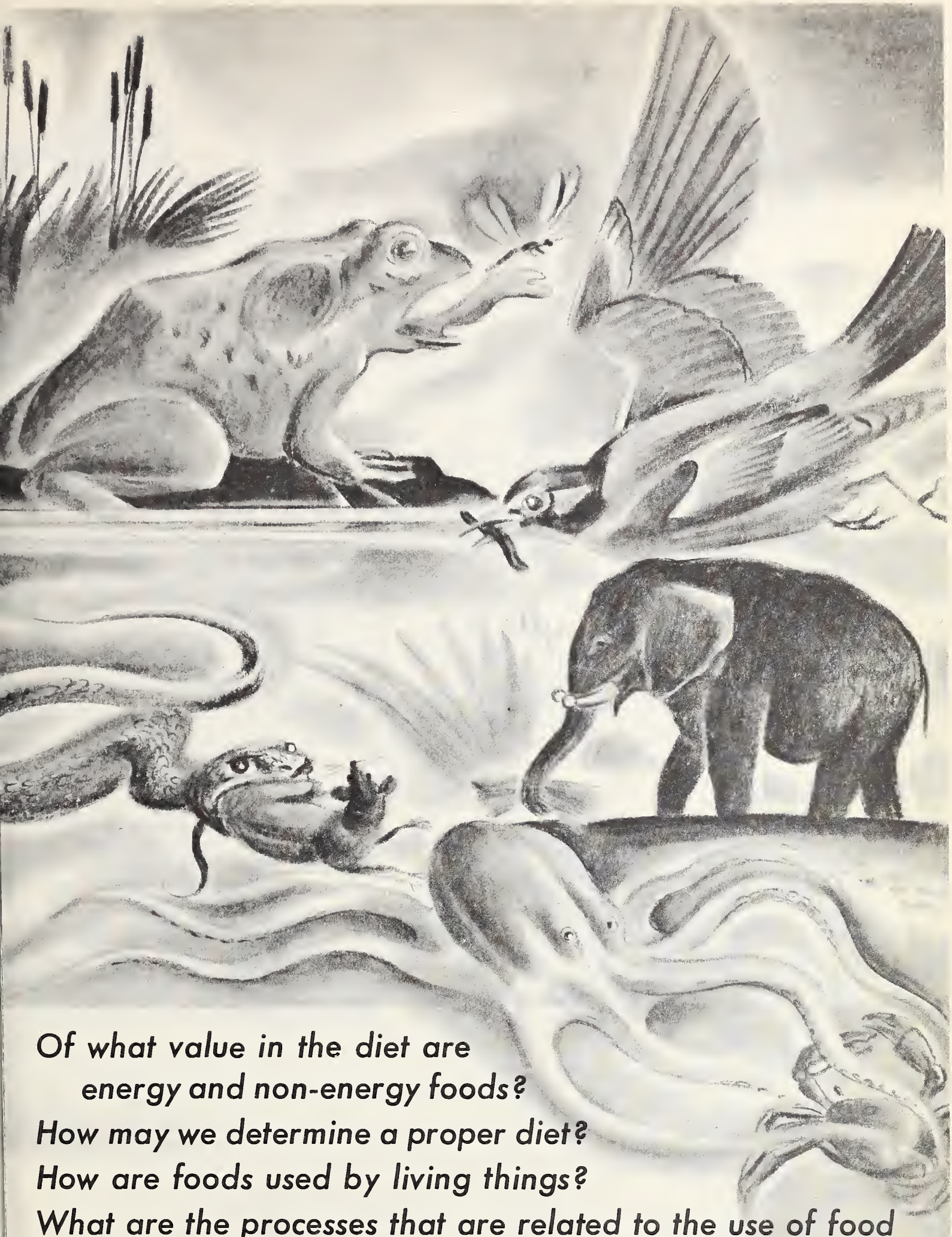






UNIT FOUR

FOOD AND LIFE



Of what value in the diet are energy and non-energy foods?

How may we determine a proper diet?

How are foods used by living things?

What are the processes that are related to the use of food in the human body?

Can you select two drawings here that illustrate each of the following principles? (1) Chlorophyll-bearing plants make their own food. (2) Parasitic organisms use their living hosts as food. (3) Many animals and some plants capture other organisms for food. (4) Many plants and animals consume dead organisms. (5) Many plants and animals consume the products of other organisms as food. Can you state other examples than those shown here to illustrate the principle Plants and animals have special adaptations for securing food?

9

FOODS AND DIET

1. Of What Value in the Diet Are the Energy Foods?

Have you any idea how great a quantity of water sixteen thousand gallons is? It is enough to fill a tank that is three feet deep, twenty feet wide, and about thirty-five and one-half feet long. Three or four times that much water would fill a large swimming pool. Now imagine how much heat would be needed to make that quantity of water boil. A good-sized fire would have to burn under it for some time to supply enough heat, even if all the heat from the burning fuel went into the water. Yet, during the four years that a boy of average size attends high school, enough heat is supplied to his body by the food he eats to raise sixteen thousand gallons of water from room temperature to the boiling point. Even then, by no means all the food he eats serves as fuel. The rest serves other important purposes, which will be discussed later.

THE CLASSES OF FOODS · [E]Foods are commonly divided into two classes. These are (1) the energy foods—that is, foods that supply energy[1]—and (2) the non-energy foods—those that do not supply energy. Every plant and animal must secure both energy and non-energy foods.

[E]The foods that supply energy[2]—namely, carbohydrates (including sugars and starches), fats, and proteins[3]—are all essential to life (illustration, p. 198). The non-energy foods that are essential are water, minerals, and vitamins. Those that are not necessary to life include coffee, tea, and spices.

The grouping of foods into the two classes of those that yield energy and those that do not is done merely for convenience. The things that plants and animals take in as food rarely fall exclusively into one of these two groups. Pure oils, fats, sugars, and starches are strictly energy foods. But they are seldom eaten in pure forms. The parts and products of plants and animals which animals and non-green plants consume as food are practically all made up of varying quantities of several energy and non-energy foods.

THE FUNCTIONS OF ENERGY FOODS · [E]The energy stored in carbohydrates, fats, and proteins is changed to other forms of energy in the living cells of all organisms. These energy changes are necessary chiefly (1) to keep the body of the plant or the animal warm enough so that its life processes can continue; (2) to carry on the processes of making the protoplasm of new cells, which are needed for growth, for replacing and repairing tissues, and for building the bodies of offspring (young); (3) to carry on the various bodily processes; (4) to move the body parts; and (5), in some organisms, to produce light or electricity.

1. Maintaining body temperatures. Every living thing loses body heat whenever the

[1]Cultivate the habit of using the Glossary and the Index in reviewing the meanings of scientific terms.
[2]Pages 170–172. [3]Footnote, p. 170.

Plants are the only sources of carbohydrates. How many of the foods suggested in these pictures furnish more than one kind of energy food?

temperature of its immediate surroundings becomes lower than its body temperature. Relatively small quantities of the energy foods which green plants make and non-green plants secure need to be changed into heat for replacing such losses. The situation with the animals, however, is much different. The portions of energy foods which different animals eat that must be changed to body heat in order that they may remain alive vary widely for the reasons that follow:

The body temperature of an invertebrate or of a cold-blooded chordate[1] changes as the temperature of its environment changes. Moreover, its temperature is always practically the same as that of the environment. Consequently, as is the case with plants, relatively small portions of the energy foods of one of these animals need to be changed to body heat.

In contrast, the internal body temperature of a warm-blooded chordate[2] remains practically the same while the animal is active, no matter how the temperature of its environment varies. Thus the normal temperature of man is 98.6° F, and that of birds is from 104° F to 110° F, depending on the species of the bird. Hence, except in extremely hot weather, a considerable portion of the food of a warm-blooded animal must be changed to body heat in order to maintain its normal body temperature (illustration on this page). When mammals hibernate,[3] however, their body temperatures may drop considerably below normal. The noted American zoologist Hegner[4] reported that a ground squirrel that was hibernating at a temperature of 35.6° F

In which situation in each pair of drawings do you think the heat losses from the boy's and girl's bodies would be greater? Why? Can you explain why smaller amounts of energy foods are needed in summer than in winter?

[1]Pages 537–547. [2]Pages 547–550.

[3]*Hibernate* (hī′bẽr nāt): to remain dormant during the winter. *Hibernation* (hī bẽr nā′shŭn): the act or state of hibernating. A dormant state, or *dormancy* (dôr′măn sĭ), is an inactive state that resembles sleep.

[4]Lived, 1880–1942.

had a body temperature of 35.6° F. In such a case, almost none of the stored food in the squirrel's body needed to be changed into heat in order to enable the animal to remain alive.

Most of the losses of body heat occur at the body surfaces that are exposed to the air (illustration, p. 199). Smaller birds and mammals have much greater surface areas in proportion to their weights than have larger ones. Also, in general, young animals have much greater surface areas in proportion to their weights than have adults. Hence robins and mice must change far greater portions of their food into heat than cattle and horses. Furthermore, young robins, mice, cattle, and horses must change much greater proportions of their food into heat than adult ones. Small animals therefore need to eat relatively great quantities of food in order to keep warm. For example, some small mammals and perhaps also some birds will eat their weights of food in a day. A shrew, one of the smallest mammals, is said to eat several times its weight of insects and other prey in a day.

Most but not all of the body heat results directly from the energy foods that are eaten. Part of it results from the friction caused by the rubbing together of muscle tissues and other structures as the organism moves about. Whenever there is friction, some of the energy of motion is changed to heat energy. How are these statements related to the last principle on page 222?

Keystone

It probably would not occur to you that getting wet might be a serious calamity to an animal. Yet it might be for any small animal. To illustrate, a bird or a mouse that becomes thoroughly wet is in serious danger of losing so much of its body heat through the evaporation of the water from its feathers or fur, while getting dry, that it may not be able to keep warm enough to survive. Haldane,[1] a famous British biologist, states that "an insect going for a drink is in as great danger as a man leaning out over a precipice in search of food."

Body temperature and activity. As has been indicated, the body processes cannot continue unless the right body temperatures are maintained. For this reason, most organisms cannot survive in extremely cold climates. For this reason, also, most plants and animals "freeze to death" in their normal habitats if the temperatures become unusually low.

[E]The activities of most living things are directly related to their body temperatures. The low temperatures of approaching winter slow down the vital processes of plants. No doubt you have observed that grass, as well as

[1]Born, 1892; still living.

deciduous trees and bushes, appears not to grow or to be active during the cold months. Also, as the weather becomes colder and as, consequently, the body temperature of an invertebrate or of a cold-blooded animal becomes lower, the vital processes of the animal slow down and it becomes less active. If its body temperature becomes low enough, the animal becomes dormant. When a rise in the temperature of its habitat brings a corresponding rise in its body temperature, it becomes active again.

In contrast, since the body temperatures of the warm-blooded animals, namely, the birds and the mammals, remain practically unchanged, the activities of these animals are affected far less by warm or cold weather. Man and most of the other mammals, and birds as well, carry on many of their activities winter and summer, with relatively little regard to any but extreme temperature changes.

2. Building body cells. *For growth.* [E]The early life of every organism is a period of growth (illustration, p. 202). The higher plants and some animals, such as snakes, crocodiles, and other reptiles, continue to grow as long as they live. During the growing period of every complex organism the body cells multiply rapidly. Hence by the time the plant or animal has reached the adult stage, it usually has increased in volume and weight many times, as the following examples will indicate:

The General Sherman tree, in the Sequoia National Park, California, is believed to be the world's largest organism. Yet when it sprouted from the seed, more than four thousand years ago, it was only a fraction of an inch long. A pig which at birth weighs only a few ounces may grow to weigh more than a thousand pounds. A human baby is expected to double its birth weight by the time it is five months old. A new-born blue whale is said to gain in size and weight faster than any other living thing. A marine sunfish is believed to increase more times in size as it grows up than any other animal. An adult sunfish sometimes grows to be nine feet long and to weigh a ton. Yet, when first hatched from the egg, it is about the size of a pin-head, and has eyes about one fourth the size of its whole body.

For regeneration. Regeneration[1] is the process by which a plant or an animal grows a new part of its body to replace one that has been destroyed. All regeneration is brought about by the multiplication of cells, or increase in their numbers, through the process of growth.

[E]Regeneration includes (1) the replacing of dead cells, (2) the healing of injuries, (3) the replacing of lost organs, and (4) the growing of a complete new individual from a part of another.

The simplest type of regeneration is the replacing of dead cells. Cells have a life cycle similar to that of the plant or animal which they compose. They are formed, they grow to maturity, they live for a longer or a shorter time, and then they die.

Dead cells are constantly being replaced by young cells in living tissues. For example, new skin cells, which are being built at the rate of several billions per day, replace the dead cells of epidermis that are constantly being worn off our bodies.

All plants, as well as all animals, can regenerate tissue to heal wounds. You probably have observed the results of such regeneration of plant tissues on the stumps of cut-off tree limbs where new tissue has grown over the edges of the cut. This new tissue heals the wound and protects the fibrovascular bundles[2] of the remaining part of the limb.

In the animals, even in the higher verte-

[1]*Regeneration* (rē jĕn ĕr ā'shŭn). [2]Page 153.

Courtesy of *Collier's*; photograph by Constance Bannister

What reason can you suggest to explain why mammals do not continue to grow all their lives?

brates,[1] breaks in the skin or injuries to almost any body structure, including the bones, are repaired, provided that the injuries are not too serious. Surgery[2] is made possible by the ability of the body to regenerate new tissue.

In the higher vertebrates all but small wounds are usually closed by the building of scar tissue. Scar tissue, however, is not like the tissue it replaces and does not carry on all the functions of the original tissue.

The regeneration of lost organs is common in plants and in the lower Metazoa.[3] In some cases even whole organ-systems are replaced. Thus, if the top of a potato plant or a dandelion plant is cut off, an entire new top will grow.

Many simple animals can regenerate almost as completely. When, for example, a sea cucumber[4] is attacked by an enemy, such as a lobster, it contracts the muscles of its body so strongly that often its body bursts open. Sometimes its breathing organs, its intestine,**[5] and practically all its other internal organs break loose and spurt out. If the lobster eats them, or becomes entangled in them, as in some instances it does, the sea cucumber may escape being eaten. If it does escape, usually its missing organs completely grow again, and its torn body walls heal.

The highest invertebrates, namely, the arthropods, frequently regenerate lost legs. Perhaps you have seen a lobster or a crayfish with a small claw or leg which is growing to replace one lost (illustration, p. 203). Even a few of the vertebrates can regenerate certain missing parts. For example, some salamanders can grow new legs and tails. Certain lizards can grow new tails which look much like the ones lost, but which have no bones (vertebrae) in the new part. The regeneration of missing parts in the higher chordates is limited chiefly to replacing such structures as skin, hair, feathers, and nails.

Many plants and lower invertebrates, if cut into parts, can grow a whole new individual from each part. Many biologists consider this process, which results in an increase in the number of individuals, a special type of regeneration. In this book it is discussed in the section on reproduction.[6]

All the facts here presented, together with

[1]Page 537.

[2]*Surgery* (sûr′jẽr ĭ): the branch of medical science that is concerned with the repair of injuries and the correction of abnormal conditions of the body, most commonly with the aid of instruments.

Surgeon (sûr′jŭn): one who practices surgery.

Surgical (sûr′jĭ kăl): concerning surgeons or surgery.

[3]Page 513.

[4]Page 525.

[5]*Intestine* (ĭn tĕs′tĭn).

[6]Pages 433–434.

others that might be stated, establish this principle: In general, the lower an organism is in the scale of life, the greater are its powers of regeneration. It has been established also that, ᴾin general, a young plant or animal of any kind has greater powers of regeneration than an old one of the same kind.

Amino acids in relation to growth and regeneration. Growth and regeneration are made possible almost entirely by proteins in the diet. The reason for this fact is that proteins are the only energy foods that contain nitrogen, and nitrogen is part of all protoplasm. Proteins are synthesized[1] (built up) in all living cells from amino[2] acids. These are compounds of carbon, hydrogen, oxygen, and nitrogen, and sometimes also of sulfur.

It is now believed that there are, in all, only twenty amino acids and that all proteins are built from these twenty.

Different organisms need different combinations of amino acids because the various kinds of living things differ in the kinds of

[1]Footnote, p. 154. [2]*Amino* (ă mē′nō).

A normal lobster on the ocean bottom. The inset shows the regenerated end of a lobster's claw. It has healed, but will never be completely normal. If, however, the whole claw had been lost, a perfect, though smaller, one would have grown in its place. How do you think such an injury as the one shown here could have been received? How do you think that the loss of a claw would affect the chances of a lobster's survival? What principle on page 222 does the large picture illustrate (illustration, p. 545)? Can you select other principles, at the ends of earlier chapters, which you think this picture illustrates also?

Lynwood Chace

Name these activities in the order of the amounts of energy that they require, beginning with the one that demands the most. Justify your answer

proteins that compose their structures. Plants and some protozoans can make all the amino acids that they need for building their proteins. Man is believed to be able to make twelve only. He must get all the others from the proteins that he eats.

Usually animals must eat a considerable variety of foods in order to get from them all the amino acids that they require. For example, if a cow were fed an adequate (sufficient) diet, except for protein, and were then given only one certain protein (zein[1]) from corn, it would soon die, no matter how much of this protein it might eat. The same would happen to a person if he should eat no protein except, for instance, that contained in gelatin. The reason is that not all the amino acids which are needed for growth and for replacing, repairing, and maintaining tissues, and which an animal's body cannot synthesize, are supplied to the cow by the corn protein or to the person by the gelatin.

In contrast with these proteins, which are deficient in necessary amino acids, are milk and cheese. These dairy products are complete proteins, supplying all the amino acids that people require.

3 and 4. Carrying on the bodily processes and moving body parts. Some energy is constantly being required in every living thing for carrying on respiration, digestion, and all other bodily processes. Additional energy is required in moving body parts while an organism is engaged in locomotion, food-getting, fighting, or any other activity. The more strenuous the activity in which an organism is engaged, the greater are the quantities of energy foods which must be changed to energy of motion (illustration, above).

[1]*Zein* (zē′ĭn). Footnote, p. 3.

5. Producing light or electricity. Many kinds of plants and animals change some energy foods into light, as well as into all the other forms of energy which have just been discussed. Several kinds of fungi are luminous (light-producing). Some years ago a report from Texas told of "mystery meat," which glowed in the dark. Its light was later discovered to be caused by bacteria living in the meat. Some luminous bacteria produce blue light, and others green. Sometimes old stumps and timbers glow in the dark with "fox fire" (a kind of phosphorescence[1]), which is caused by luminous fungi.

Often on a dark night the ocean will be seen to gleam dully with greenish light produced by countless millions of micro-organisms or of larger organisms such as sea walnuts (Ctenophora (illustration, p. 534)). There are many kinds of "glow-worms." Probably the most unusual of these is the South American "railroad worm." It has luminous yellow spots along its sides and a luminous red spot at one end. The illustration on page 206 shows other organisms that change to light energy the energy which they obtain from eating carbohydrates, fats, and proteins.

Certain kinds of fish are able to change some of their food energy into electrical energy, as well as into heat, growth, motion, etc. The kinds that have the most completely developed electric organs are the electric eel of Brazil and certain African catfishes. These animals can deliver a strong electric shock, which has survival values in enabling them to capture prey and to fight enemies. A torpedo ray, a more simple fish-like chordate,[2] has even more powerful electric organs. One of these rays, two or three feet in width, has been known to disable a man with a single shock.

2. *Of What Value in the Diet Are the Non-energy Foods?*

During the Second World War the greatest danger to people who escaped in small boats from ships that were sunk and from planes that fell into the ocean was the lack of fresh water. These survivors did not dare drink the ocean water. Instead of quenching thirst, salt water makes it more intense. Various devices were invented with which people in such situations could procure drinking water. One of the most unusual of these provided means of catching sea fish and then of squeezing from their bodies enough fluid, chiefly water, to maintain human life.

THE ESSENTIAL NON-ENERGY FOODS · **Water.** It is not surprising that considerable quantities of water can be obtained from the bodies of fish. The bodies of all living things consist partly, and most of them chiefly, of water. The body of a jellyfish is about 99 per cent water. In contrast, a relatively small fraction of the body of a great tree is water, because most of the tree's trunk consists of dead wood. The only living tissue, the cambium, is in a narrow cylinder inside the bark.[3]

The body of an average man or woman contains about fifty quarts of water. In the human body the percentages of water in the different tissues vary from about 30 in the bones to about 83 in the kidneys. About one tenth of the total amount of water in the human body is part of the blood.

[1]*Phosphorescence* (fŏs fō rĕs'ĕns).

[2]Page 536. [3]Page 161.

[E]Water performs several unique and essential functions in the bodies of all plants and animals: (1) it dissolves minerals, food substances, oxygen, and waste materials; (2) it carries food materials to all the living cells and carries waste materials away from them; and (3) it forms part of every body fluid. Water performs an additional function in the bodies of all animals high enough in the scale of life to have digestive systems (most invertebrates[1] and all vertebrates[2]): it makes possible the passage of food materials through the digestive system.

All living things are constantly losing water. The average person loses about three

[1]Page 513. [2]Page 539.

Organisms that change some energy food into light energy · Some organisms, such as the fire-fly and certain deep-sea fishes, have luminous organs. Others, such as this shrimp, send out a fluid which instantly becomes luminous in the water. Others, like this crustacean, have their light-producing structures distributed. Some of the deep-sea fishes have no light-producing organs, but light-producing bacteria live in certain of their structures. In earlier times fox fire was regarded with superstitious fear. Which of the other items in "As Scientists Think" (p. 571) is related to this last statement?

quarts of water daily by the evaporation of perspiration, by excretion,**[1] and by evaporation from the lungs. The illustration on page 209 shows the chief sources from which this water is replaced.

Minerals. As has been said, minerals[2] are an essential part of all protoplasm and hence of every living cell. Also, non-living structures, such as the shells of snails, clams, and other mollusks,[3] the exoskeletons of crabs and other crustaceans,[4] and parts of the bones, nails, horns, and teeth of chordates,[5] are composed largely of minerals.

Minerals are needed in the proper proportions in all living cells because they help to regulate physiological[6] processes, such as the use of food by the cells, and the proper functioning of the muscles, including, in the higher animals, those of the heart. The importance of minerals in relation to hidden hungers is discussed in another part of this book.[7]

Minerals are constantly being lost in the waste materials from the body and must be replaced. So much salt escapes from the body in perspiration during warm weather that people are sometimes rendered unable to carry on their daily tasks effectively. Such people often take salt tablets to restore their salt content. The illustration on page 209 shows some important sources of minerals.

Vitamins. Vitamins are regulators. They regulate the vital processes of living things by keeping the various organs functioning effectively. Every plant and animal needs some of them, but organisms do not all require the same vitamins. For example, vitamin M is known to be important to monkeys, and H to chicks, but neither is yet known to be of any importance to man.

Vitamins are organic compounds. They are made up chiefly of different combinations of the elements carbon, hydrogen, and oxygen. Each is specific,—that is, it has definite and unique effects upon certain vital processes,—but often several vitamins affect the same process. Thus, by regulating the bodily functions, certain ones (1) prevent and cure specific diseases; (2) assist in digestion, growth, reproduction, and the healing of wounds and bone injuries; (3) assist in the clotting of blood; and (4), in people, affect attitudes, mental health, and intelligence.

Sources and values of vitamins. The illustration on pages 210–211 shows the sources of vitamins important to man. Plants are believed to be the original sources of all vitamins. Some vitamins are synthesized within the bodies of animals from substances obtained by eating plants. Such vitamins include A, D, G (or riboflavin,[8] B_2), and K.

Vitamin A is manufactured from a yellow-red substance produced by carrots, rutabagas, and many other green plants.

Vitamin D is formed in the skin when a certain fat (ergosterol[9]) is exposed to ultra-violet light, either from the sun or from an artificial source, such as an ultra-violet lamp. More than enough of vitamin D is made for the body's needs during the summer. Al-

[1]*Excretion* (ĕks krē′shŭn) includes all the processes by which living things *excrete* (ĕks krēt′), or get rid of waste materials from their bodies. Excreted materials are *excreta* (ĕks krē′tȧ). *Excretory* (ĕks′krē tō rĭ): having to do with excretion.

[2]Although it is common practice to speak of "minerals" in food, what is meant is not *minerals* but certain *elements*, the original source of which is minerals in the soil (footnote, p. 66).

[3]Page 524. [4]Page 530. [5]Page 537.

[6]*Physiological* (fĭz ĭ ō lŏj′ĭ kăl): pertaining to *physiology*** (fĭz ĭ ŏl′ō jĭ), which is the branch of biology that deals with the functions of the organs and other structures of living plants and animals. The study of the structures themselves forms the branch of biology called anatomy* (ȧ năt′ō mĭ).

[7]Pages 92–94.

[8]*Riboflavin* (rī bō flā′vĭn).

[9]*Ergosterol* (ẽr gŏs′tẽr ōl).

though most vitamins cannot be stored in the body, surplus vitamin D is stored in the skin, in the summer, for future needs. In the winter, however, it often needs to be supplied by foods naturally rich in it or to which it has been added, or by those in which it has been formed by irradiation, that is, by their being exposed to ultra-violet radiations.

Vitamins G and K are normally made by certain bacteria that live in the intestines. Vitamin C is not made in the human body, though it is synthesized in the bodies of all other mammals, with a few exceptions, which include apes and guinea pigs. The vitamins that are made in the human body can also be secured, if necessary, directly from foods, as the other essential vitamins must be.

Chemists have learned to synthesize the vitamins most important to human welfare and to make them available in various forms. There is no doubt of the value of these preparations when taken as prescribed by physicians to supply certain definite needs. Vitamin tablets were consumed with excellent results during the Second World War by the armed forces to supplement their rations and by the peoples of countries where, because of the war, a complete and well-balanced diet could not be provided. The need of them is still vital in all the countries injured by the war. In fact, vitamins will always be needed, in great quantities, in every country whose population has an inadequate diet.

[E]Vitamins are not "used up" in the body and are lost only through excretion. Hence the amount of any vitamin needed for maintaining health is small. The widespread practice, therefore, of taking vitamin tablets without a doctor's advice, and merely with the hope that they may bring benefits, is always expensive, often needless, and in some cases harmful, if not actually dangerous. Several experiments such as the one described on page 222 (No. 2) indicate that healthy people who have an adequate diet receive no benefit from taking extra vitamins.

Alcoholic beverages drunk before or with meals are known to reduce, if not to destroy, the effects of vitamins of the B group.

Diseases due to vitamin lacks are discussed in another part of this book.[1]

THE NON-ESSENTIAL NON-ENERGY FOODS · **Coffee and tea.** In the fifteenth century, coffee was considered by the Mohammedans as an intoxicating beverage, and its use was forbidden by the Koran (the scriptures of the Mohammedans). For some time after coffee had been introduced into Europe in the sixteenth century, it was widely believed to be a poison. So also was tea, at that time. Gustavus Adolphus, king of Sweden, determined to find out how poisonous coffee and tea actually were. To do this he condemned twin brothers, who had committed murder, to death through drinking these beverages. He sentenced one brother to drink coffee; the other, tea. Doctors were appointed to decide how much of each beverage would be a fatal dose and to observe and record the results.

The sentences were carried out. Every day each brother was made to drink the quantity of coffee or of tea which the physicians had directed. Years passed. At length the doctors died, one after another. But the brothers lived on. At last, the tea-drinking brother died at the age of eighty-three. The records do not reveal how much longer the coffee-drinking brother survived.

Both tea and coffee contain caffein,[2] a nerve stimulant. Caffein increases the rate of the heart-beat and the activity of the kidneys and perhaps of other organs. By increasing the circulation of blood through the brain, it

[1]Pages 294–296. [2]*Caffein* (kăf′ē ĭn).

Water is formed as a waste product whenever cells use food. Much of the water that an organism needs is thus supplied. How do you account for the fact that some desert animals never drink water? Can you suggest one or more questions that could be answered from this illustration?

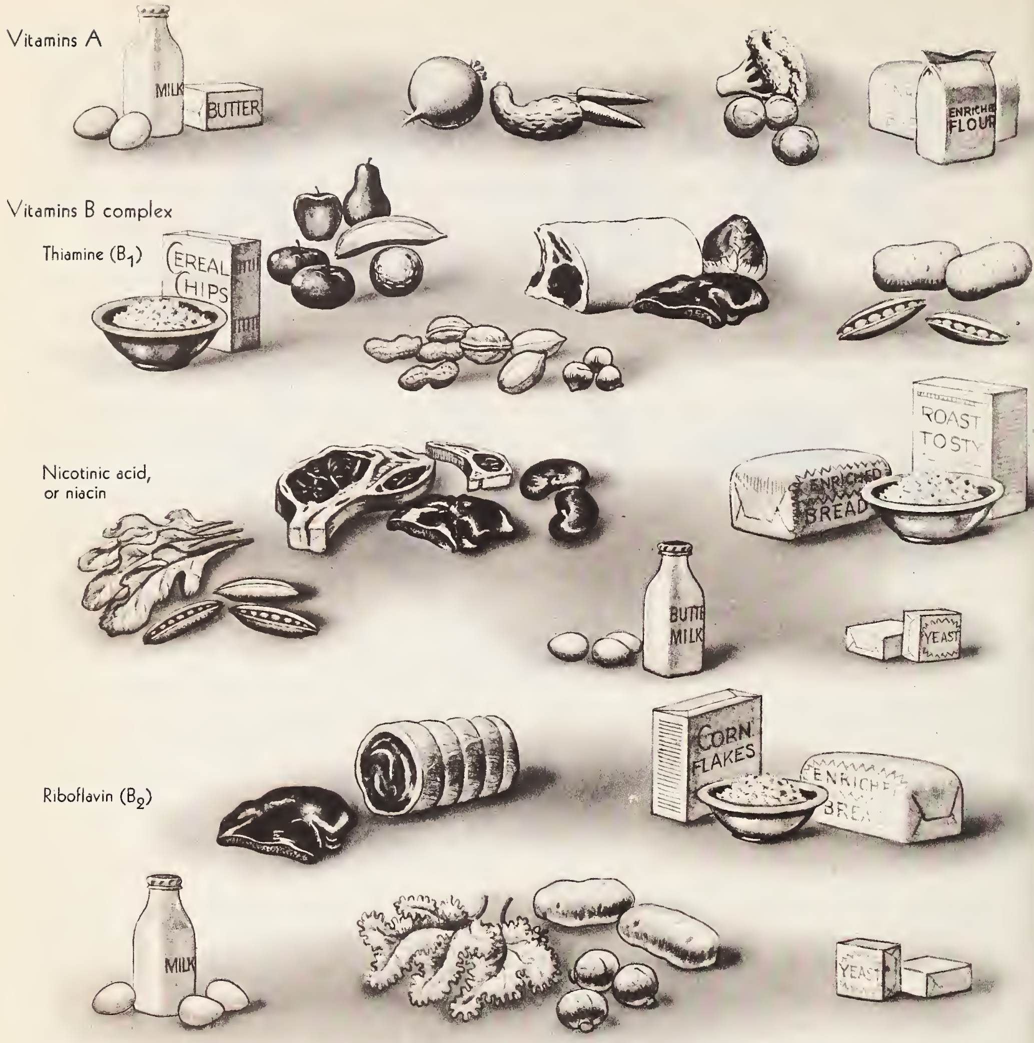
helps to overcome fatigue and is therefore refreshing.

E Although pure caffein is poisonous if taken in large doses, it probably does no harm to most adults in the amounts consumed in coffee and tea. The results of experiments, however, in which large amounts of coffee and tea were given, over long periods, to laboratory animals (rats, mice, and guinea pigs) indicate that these beverages may be harmful to children. Some people are allergic[1] (sensitized)[2] to coffee and tea and consequently suffer various ill effects from their use. Also, an occasional person's digestion may be disturbed somewhat by coffee. But any harmful effects that are observed to result from drinking coffee and tea are temporary. They disappear when the beverages are eliminated from the diet.

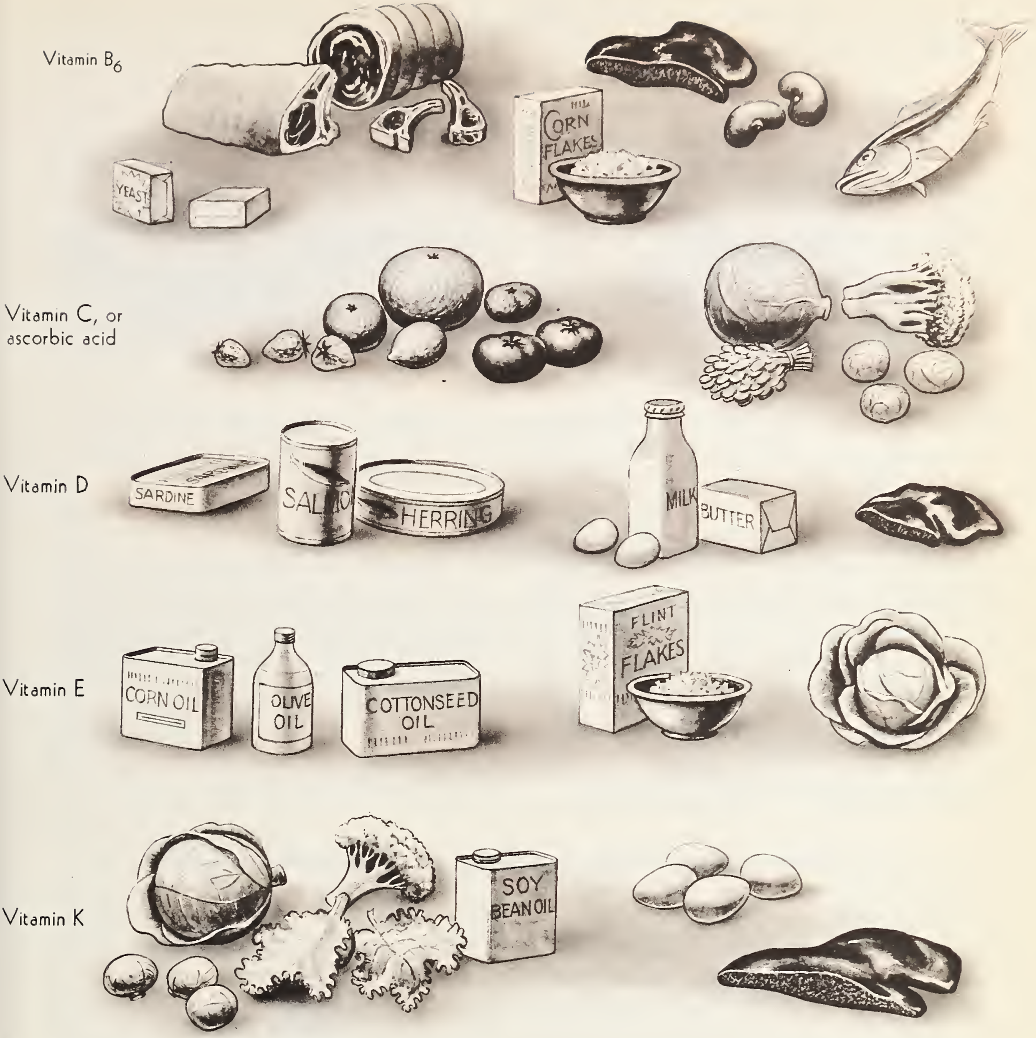
Spices. Pepper and other strong spices are believed to have been originally used, especially in tropical countries, to disguise, or "cover up," the flavor of spoiled meat. Without means of refrigeration, people were often unable to consume a large animal before some of its meat had become partly decayed.

Through the centuries people learned to use many spices in various ways which not

[1] *Allergic* (ă lûr′jĭk). Pages 296–299.
[2] *Sensitized* (sĕn′sĭ tīzd).



Not all the vitamins known to be essential are included in this illustration, but a diet made up of the various groups of foods shown here will include all the essential vitamins



Consumer Biology: Secure the opinions of doctors in your community concerning the values and the possible dangers of taking vitamin "pills" without a doctor's advice

only improved the flavor of the food, but also stimulated the appetite and the digestion.

PRESERVING FOODS · For centuries, perhaps even for thousands of years, people have known how to keep foods from spoiling, for a longer or shorter time, by drying, smoking, salting, or cooling them, or by combining these processes. Long ago, too, they discovered that sugar and vinegar would preserve some kinds of food. In 1795 Appert, a Parisian chef, invented a method of preserving foods in glass jars. Since then many improvements have been made in canning foods.

The success of every method of preserving foods depends on its being able to prevent or to delay in the food the multiplication of fungi which would consume it. In all canning methods, for example, the foods are first heated hot enough to kill the fungi[1] that cause foods to spoil. They are then sealed in air-tight bottles, jars, or cans, where no living organisms can get to them. In each of the other methods, the food is rendered and kept too dry, too cold, or otherwise in such a condition that the fungi cannot thrive in it.

Within the past few years, great advances have been made in methods of preserving foods. More rapid and more effective ways of dehydrating, or drying, not only make the foods "keep" indefinitely, but also make possible their storing and shipping with a great saving of space (illustration, p. 216). The process of the rapid freezing of fresh fruits, vegetables, fish, and other foods, and of keeping them at low temperatures, makes fresh foods available throughout the year. Rapid freezing causes the water inside the cells of the food substances to form small ice crystals. These do not break the cell walls, as would large crystals formed by slow freezing. Thus the foods remain in almost the same condition as when they were frozen

Individual food-preservation lockers or units can now be rented in refrigeration plants or bought for homes. Many modern refrigerators likewise have "deep-freeze" units. Fruits, vegetables, meats, and poultry are put into them at the times when the various foods are most plentiful, and are consequently cheapest, to be eaten months later.

3. How May We Determine a Proper Diet?

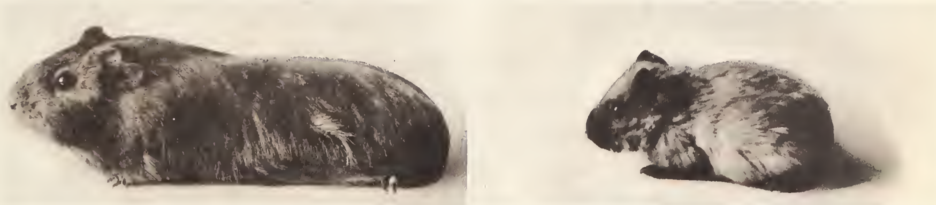
Until near the end of the eighteenth century, nobody knew what the source of the heat is in the bodies of the higher animals. Scientists had advanced several hypotheses.[2] Some thought that animal heat resulted from the friction of the blood as it circulated through the animals' bodies. Others thought that animals were kept warm by some sort of mysterious fire that was always burning in their bodies.

AS SCIENTISTS WORK AND THINK · **A hypothesis.** Neither of these hypotheses satisfied Lavoisier.[3] This French chemist had become famous for his experiments on the nature of combustion. He knew that heat is given off whenever carbon oxidizes, that is, whenever it combines with oxygen in ordinary burning. He knew also that whenever fuel burns, carbon dioxide and water are formed. Hence it seemed to him sensible to suggest that the heat in an animal's body is probably produced in the same way that heat is produced when a substance burns, namely, by the combining of oxygen from the air with carbon in the animal's food.

[1]Page 557. [2]Page 590, No. 10.

[3]*Lavoisier* (lȧ vwȧ zyā'). Lived, 1743–1794.

THE DISCOVERY OF VITAMINS



Dr. Percy R. Howe, Forsyth Dental Infirmary

These two guinea pigs were from the same litter. The diet of the smaller one was lacking in vitamins. Do you think that these pictures *prove* anything, or do they merely *indicate* a probable fact? Explain. (See "As Scientists Work," p. 590)

ALL THAT WE KNOW about the different vitamins themselves has been discovered by scientists during the past half-century. Several hundred years ago, however, men learned to use foods now known to contain vitamins, as a means of improving health. Toward the end of the sixteenth century Dutch and English commanders of warships found that the addition of either lime juice or lemon juice to the ship-board diet of salt meat and ship's biscuit would prevent the dreaded disease scurvy. These discoveries were made not by long and careful experiments by scientists, but purely by trial and error, that is, by trying one thing after another until the right thing happened to be tried. By 1795 laws were passed requiring all ships of the British navy to supply limes or lemons to the sailors. In 1863 a similar law was passed for the British merchant marine.

The actual scientific study of deficiency diseases may be said to have begun with the work of a Dutch physician, Eijkman,[1] in the Dutch East Indies. During the eight-year period from 1889 to 1897, he established the fact that beriberi could be prevented and cured by adding rice bran to the diet. Later many scientists of different institutions and countries carried forward the study of deficiency diseases. Each used freely, as scientists always do, the discoveries that had already been reported.

The first vitamin to be discovered was vitamin C. Its existence was announced by Holst (German) in 1912. During the period from 1915 to 1922, McCollum (American) discovered vitamins A, D, and B (the B-complex group). In 1922 Bishop and Evans (Americans) discovered vitamin E. In 1935 Danish scientists discovered vitamin K. In 1937 Szent-Gyorgii[2] (Hungarian) discovered niacin (a vitamin of the B complex).

The preceding list is only a partial one of scientists who have discovered vitamins or whose experiments have led to their discovery. An interesting bulletin-board display could be made of clippings, from magazines and newspapers, containing current facts about vitamins.

[1] *Eijkman* (īk′män).

[2] *Szent-Gyorgii* (sĕnt dyûr′dyĭ).

When he announced this hypothesis, other scientists gave it little attention. Most of them, no doubt, thought it absurd. But Lavoisier was not discouraged by this unfavorable reception of his hypothesis. He at once planned an experiment to test it.

The experiment. He built two small rooms just alike and completely surrounded them with ice. He placed a burning candle in one room and a live guinea pig in the other. After a definite length of time he measured the rise of temperature in each room. He measured

Ways of retaining vitamins in food · When vegetables are cut with a steel knife, minute particles of steel from the blade hasten chemical action (oxidation) which to some extent destroys vitamins. What do you infer to be the effects of cooking upon vitamins? What do you infer to be the reasons for the statements under *B* and *D*?

A Cut raw vegetables for a salad into good-sized pieces with a plastic knife and prepare the salad just before serving it

B Eat some fruits and vegetables raw and eat the skins if you can

C Cook vegetables quickly, in a little water and in a closed kettle

D Eat fruits and vegetables as soon as possible after they have been gathered

lso the amount of carbon dioxide from the urning candle in one room and that from the reathing of the guinea pig in the other. tarting with these facts, he was able to de-ermine that the quantity of heat given off er gram of carbon in the burning candle was lmost the same as that given off per gram of arbon consumed from energy foods in the uinea pig's body.

The results. From these results he con-luded that his hypothesis was correct. He ad secured evidence which clearly indicated hat the process by which heat is produced in n animal's body is the same as that by which is produced when a candle burns, namely, each case, by the combustion of carbon. oday all scientists accept the conclusion that eat is produced in animals' bodies by the xidation of food. It forms the basis for de-ermining the amount of food needed for an dequate human diet.

MEASURING FOOD VALUES · Since Lavoi-er's time much scientific work has been done o determine how much heat the different inds of foods produce in the human body. Ieat from the combustion of food is measured Calories. A Calorie*[1] is the quantity of eat needed to raise the temperature of one ilogram (2.2 pounds) of water one degree entigrade. It is approximately the quantity f heat needed to raise the temperature of a uart of water about two degrees Fahrenheit llustration, p. 217).

METABOLISM · Every living cell of a plant r an animal manufactures substances called nzymes.**[2] Enzymes are special organic compounds that stimulate chemical action in the cells without themselves being "used up" or changed. In this respect they are much like vitamins. Without the B vitamins, more-over, the cells cannot make their enzymes.

[E]Enzymes are chiefly responsible for metab-olism.*[3] Metabolism includes (1) the oxidiz-ing of food, which changes the energy stored in food to heat and other forms of energy, (2) the breaking down of protoplasm and the building of new protoplasm, (3) the passing of waste materials out of the cells, (4) the storing of food in tissues, and (5) all other processes concerned with the use of food by living cells.

There are various factors that affect the rate of metabolism in a normal person, and, in fact, in all organisms. These include (1) conditions associated with eating, diges-tion, and other bodily processes, (2) the kind of physical activity in which the person is engaged, and (3) changes in the temperature of the surroundings.

BODILY PROCESSES AND PHYSICAL ACTIVITY · Metabolism must go on constantly because energy is needed for growth, digestion, and all other bodily processes. These processes are constantly varying as a result of innu-merable factors. Hence their changes affect the rate of metabolism.

Physical activity of every sort demands great quantities of energy in addition to those required for the bodily processes. Hence,

[1]This is the large Calorie (kăl′ō rĭ), used in physi-ogy and other biological sciences. The small calorie, hich is one thousandth of the large Calorie, is used r heat measurements in physics.

[2]*Enzyme* (ĕn′zīm).

[3]*Metabolism* (mĕ tăb′ō lĭz′m). Metabolism con-sists of two processes, *anabolism* (ȧ năb′ō lĭz′m) and *catabolism* (kȧ tăb′ō lĭz′m). Anabolism includes all the processes that are concerned with the synthe-sizing, or building, of protoplasm from simpler sub-stances. Catabolism includes all the processes that are concerned with the breaking down of protoplasm, that is, changing it into simpler substances. Anabo-lism and catabolism are both going on at the same time in every living plant or animal cell.

in order to supply this extra energy, the rate at which metabolism takes place must increase. After the activity has ceased, some time must elapse before metabolism returns to its normal rate. The amount of increase in the rate of metabolism and the time required for the rate to return to normal both depend on how strenuous the activity has been and how long it has continued. In most cases the normal rate of a person is restored within half an hour (illustration, p. 218).

CHANGES IN THE TEMPERATURE OF THE SURROUNDINGS · As has been stated, a person's internal body temperature ordinarily remains practically unchanged. This is so only because the rate of metabolism changes as the temperature of the surroundings changes. When the body is exposed to cold, metabolism tends to increase. Heavy clothing makes the rate of metabolism under such conditions less than it otherwise would be. If one's body becomes chilled, one begins to shiver. Shivering raises the rate of metabolism. Thus it produces more heat to keep the body warm, just as violent physical exercise does.

If, in warm weather, too much heat is produced in the body, its temperature is brought back to normal (1) by the enlarging of the blood vessels near the skin, which permits more body heat to escape, and (2) by the increase of perspiration, which, as it evaporates, takes heat from the body, just as water, as it boils, uses heat from fuel.

BASAL METABOLISM · If a person does not eat for at least twelve hours, and then lies

About 41 pounds of water were taken out of 60 pounds of pork to make less than 20 pounds of dehydrated pork. **Topic for Individual Study:** Find out in encyclopedias and books on nutrition all you can about the history of food preservation. How are modern pressure canning and refrigeration effected? Can you suggest at least three advantages which result from our being able to preserve foods?

Knell, from United States Department of Agriculture

Careful measurements have shown that fats, when oxidized, or burned, inside the body, produce 9.3 Calories per gram and that carbohydrates and proteins each produce 4.1 Calories per gram. In other words, any weight of fat is changed in the body into more than twice as much heat energy as the same weight of sugar, starch, or protein. Sugars are changed into heat energy quickest and fats slowest. Can you suggest a reason why soldiers, mountain-climbers, and others engaging in long periods of exhausting activity carry candy to eat?

quietly in a comfortably warm room, his rate of metabolism closely approaches that needed merely to maintain his bodily processes. This rate is known as the *basal-metabolism rate* or the *basal metabolism* of the person. Ways of determining basal metabolism have been perfected. It is measured in Calories because all the energy furnished by food is finally changed to heat (illustration above).

[E]Average basal metabolisms have been determined, from hundreds of measurements, for people of either sex and of various heights, weights, and ages. If a person's basal metabolism varies greatly from that of an average person like him, the fact probably indicates that his diet does not include the proper quantities of energy foods. Sometimes, however, it indicates to a physician an abnormal condition which needs to be corrected.

PLANNING A HEALTHFUL DIET · A healthful diet must provide both an adequate amount and a sufficient variety of food. We are accustomed to think of only certain things as being proper foods. There is, however, almost no limit to the variety of animals and plants that can serve as human food. No doubt ancient man commonly ate numerous plants and animals which civilized man would eat only under dire necessity.

Previous to the Japanese attack on Pearl Harbor, an eminent Japanese biologist spent many years in finding out what plants and animals native to Japan could serve as food in case of an extreme emergency. He finally was able to construct well-balanced, adequate diets of foods that *could* be obtained almost anywhere in the Japanese islands. The parts of these diets that had to be bought could be purchased at a total cost of about five cents per person per day. The foods suggested included weeds, parts of trees, insects, and practically every kind of small animal that could be caught and eaten. These diets would not

be pleasant, but they would maintain a healthy population.

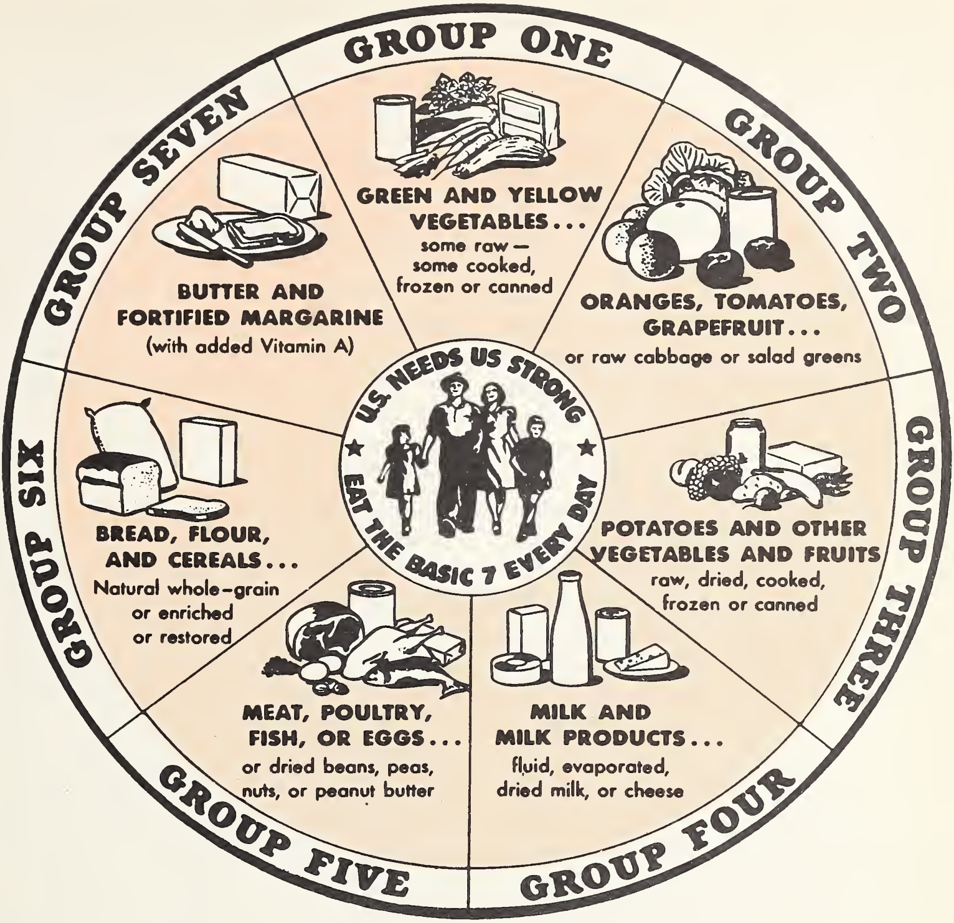
During the early stages of the Second World War the peoples of some of the warring nations had a sufficient quantity of food, yet not enough variety. They could not avoid diets that had too great a proportion of starches and sugars, and too small quantities of proteins, vitamins, and minerals. These conditions still prevail and may continue to do so for many post-war years. Even in the United States and Canada, where all essential foods can be had in abundance, many people fail to have properly balanced diets. The table on page 226 shows the numbers of Calories and other essentials that common foods supply.

THE "BASIC SEVEN" · During the Second World War the scarcity, or shortages, of meats, butter, and many other foods in the United States and, to a smaller extent, in Canada made it necessary for people to plan their diets more carefully than ever before. To help them in doing so, the agencies of the United States government that were concerned with food problems prepared and widely distributed the chart shown on page 219. Also, they made available, in the *Consumers' Guide*[1] and other publications, practical information on many aspects of food consumption, such as how to balance the diet, to raise food in gardens, to preserve surplus fruits and vegetables, and to use vitamin tablets wisely. As a result, the people on the whole were more adequately fed than they had been in pre-war times.

The "nutrition wheel" emphasizes the need of a widely varied diet. Different fresh fruits and vegetables are needed as the sources of carbohydrates, vitamins, and minerals. Different plant and animal parts and products are necessary to supply various proteins and hence all the required amino acids. Dairy products, cereals, meats, and fish must be used to provide the variety of needed fats.

[1]Published by the United States Department of Agriculture.

The relative numbers of Calories that would be used per pound of weight of the persons if each carried on the activity for the same length of time.
What activities that you perform every day do you think would use the greatest, and which the smallest, number of Calories?



The National "Nutrition Wheel," Prepared by the United States War Food Administration · Everybody should eat some food from each of these groups every day. The War Food Administration suggested also that the family money that could be spent for food be divided into five parts and that one part be spent for foods in each of these five groups: (1) milk and cheese; (2) fruits and vegetables; (3) meat, fish, and eggs; (4) bread, flour, and cereals; and (5) fats, sugars, and accessories (condiments). Show how this plan can be used along with that shown in the "nutrition wheel"

The "nutrition wheel" further makes clear that a diet made up entirely of the cheapest and most easily obtained foods will not be a balanced one. Some of the more expensive foods are essential. Milk, for example, as a complete protein and as a source of important minerals, fats, and vitamins, is a necessary part of young children's diet, whatever it may cost. Meat, fish, cheese, and eggs supply our bodies with more of the needed amino acids than do the vegetable proteins. Hence it is good economy to provide some of these more expensive animal parts and products. Some economies can be practiced, however, in buying the necessary foods. For example, the less expensive cuts of red meat (muscle tissue) furnish as many amino acids and desirable fats as the expensive cuts. Also, a straight meat diet of muscle tissue is much less healthful than a diet of muscle tissue supplemented with less expensive hearts, livers, kidneys, and tripe (prepared from the walls of the stomach).

Proteins are not needed as sources of Calories. The cheaper starches and sugars supplied by cereal products, fruits, and vegetables will provide all these that are needed. But only the proteins will furnish amino acids. Most American and Canadian families, however, probably depend more on meat for their proteins than is actually necessary.

BULK IN THE DIET · In theory it would be possible for us to supply all our energy requirements by eating relatively small quantities of pure fat, starch, sugar, and protein, and to satisfy our requirements of vitamins and minerals by taking the necessary quantities in tablets. If we were to try such a plan, we should not be healthy, and we should not live long. Through thousands of years the human body has used the food materials as these occur in nature. As a result, it has adapted itself to bulky, not highly concentrated, foods. Along with the essential foods, there are cellulose fibers and other materials which serve an important need in providing bulk in the diet. These are especially abundant in fruits and vegetables.

DIETING · Whenever a person is heavier or lighter than he should be, he can usually bring his weight to normal by eating the proper diet. One can lose weight by eating smaller quantities of fats, starches, and sugars. The body then supplies the lack of fuel by using fat and sugar stored in its tissues. Weight can be gained by increasing the quantities of fuel foods eaten.

[E]There are drugs and "medicines" for sale that increase the metabolism rate and therefore burn up more fat in the body. Hence they will reduce one's weight. But nobody should take such preparations without competent medical advice. In fact, it is dangerous to follow any sort of special diet except on the advice of a competent physician.

Alcohol and the diet. The scientific evidence available indicates that alcoholic liquor, drunk before or during meals, results in more harm than benefit. Moreover, the person who drinks excessively is likely not to have a properly balanced diet. The result may be a serious injury to his physical and mental health.

FOOD ADULTERATION · [E]Many foods that we buy are adulterated; that is, they have substances added (1) to prevent their spoiling; (2) to give them an appearance which is more attractive or is more nearly like that which the products are expected to have; (3) to add to their weight; or (4) to reduce manufacturing costs. Examples are formaldehyde in milk, mineral oil in salad dressing, yellow coloring in butter, chicory in coffee, gelatin

in ice cream, and molasses in rye bread (to darken its color).

Sometimes the adulterant is harmful, even in small quantities, as formaldehyde (a poisonous germicide) in milk. Sometimes it is only slightly harmful, as mineral oil (which causes the body to get rid of certain vitamins too rapidly) in salad dressing. Sometimes it is harmless but without food value, as yellow vegetable coloring in butter and white sand in sugar. Sometimes it is wholesome and has some food value, as chicory in coffee, gelatin in ice cream, and molasses in rye bread.

National laws have been passed, in both Canada and the United States, which require that the label on a packaged food state the exact weight and contents of the package (illustration, p. 224). The label is required to state also the nature and amount of preservative contained, if any. The most recent of these laws provide penalties for making false claims in the advertisements of any foods. These various laws cover not only foods, but also drugs, medical devices, and cosmetics. It is likely that other laws to protect the consumer will be passed in the near future.

Checking What You Know

BIOLOGICAL FACTS · You should review from time to time the explanation of these types of tests in "This Book and You," p. xiv. (*Do not write in this book.*) **Pages 194–205.** **1.** Cold-blooded animals are those whose body temperature (1) varies with the surrounding temperature; (2) remains the same when the surrounding temperature rises; (3) remains the same when the surrounding temperature falls; (4) is always lower than the surrounding temperature; (5) is usually higher than the surrounding temperature.

2. The body temperature of warm-blooded animals (1) never changes; (2) is always higher than the surrounding temperature; (3) is usually the same as the surrounding temperature; (4) remains about the same so long as the animal is active; (5) rises during hibernation.

3 State five uses which plants and animals make of the energy that they obtain in the form of food.

4. The healing of a cut finger is an example of __?__.

5. In general, fishes would be expected to have greater powers of regeneration than (1) the Protozoa; (2) worms; (3) insects; (4) sponges; (5) dogs.

6. Organisms build up *proteins* from amino acids.

7. Amino acids are made up of the same elements as are sugar and starch, namely, carbon, hydrogen, and oxygen, with the addition also of __?__.

Pages 205–212. **8.** In what four ways is water essential to living things?

9. The bones, hair, and teeth of animals will not develop properly unless the diet contains enough (1) sugar; (2) starch; (3) amino acids; (4) proteins; (5) fats.

10. State four functions of vitamins.

11. State four ways of retaining vitamins in foods.

12. *Proteins* produce more heat in the body per gram than do *fats* and *carbohydrates.*

13. Non-energy foods believed to be more harmful to young people than to adults are __?__ and __?__.

14. Name and describe five methods of preserving foods.

Pages 212–221. **15.** Heat is produced in living things by the *oxidation* of food.

16. A Calorie is the amount of heat needed to raise the temperature of a quart of water about *ten* degrees Fahrenheit.

17. State five cell processes that are included in metabolism.

18. Your rate of metabolism is higher when you are reading a book than when you are (1) running; (1) playing a team game; (3) practicing with a musical instrument; (4) lying asleep; (5) walking to school.

19. By studying a patient's rate of --?--, a doctor is often able to determine whether or not the patient is in good health.

20. Name one or more foods in each of the "basic seven" groups.

21. Soaking dressed chickens in water to make them weigh more before selling them is an example of food --?--.

BIOLOGICAL PRINCIPLES · Read the instructions on page 37.

1. All living things require food to supply their bodies with materials for the production of new cells and for the repair of injured or worn-out tissues.

2. Food furnishes living things with materials from which they obtain energy for carrying on all the activities of life.

3. In order to survive, every living thing must maintain a certain body temperature, which results from the oxidation, or burning, of food in its cells.

4. All living things require water because the functioning of protoplasm depends on a sufficient supply of water.

5. All living things require not only energy foods, but also non-energy foods.

6. All living things depend directly or indirectly on photosynthesis for food.

7. Energy is changed from one form to another, but is not created or destroyed.

BIOLOGICAL TERMS

**cold-blooded animal	**metabolism
**enzyme	**vitamin
**excretion	**warm-blooded animal

Applying and Extending What You Know

AS SCIENTISTS WORK AND THINK · 1. Some radio programs which advertise vitamins make many claims of benefits to be obtained from taking them. Which of the scientific attitudes (p. 571) should you apply as you hear these claims?

2. During the Second World War the following experiment was conducted by the United States army[1]: Two hundred volunteers were divided into five groups. For thirty days one group took vitamin tablets and yeast-extract tablets; another took vitamin tablets and liver-extract tablets; a third took vitamin tablets and sugar tablets; a fourth took vitamin tablets only; and a fifth took sugar tablets only. Nobody in any group knew what the tablets that he was taking contained. Every man kept a daily record of his weight; his change in appetite, if any; his "pep," or energy; and any symptoms that might indicate sickness. The report of the experiment stated that "no significant increase was noted in appetite, energy and 'pep,' 'gas' and indigestion, general health, or weight among the various groups." What conclusions would you draw from these facts? Which of the elements of scientific method (p. 570) are illustrated in this experiment?

3. Some time ago scientists established the fact that riboflavin (vitamin B_2) develops naturally in the intestines of ruminant animals (oxen sheep, goats, etc.) and rats. To find out whether it is manufactured also in the intestines of human beings, they performed this experiment: For three months they gave each of twelve young boys a small amount of riboflavin. They found

[1]*Journal of the American Medical Association*, November 25, 1944.

The flavor and even the odor and sight of food, if pleasant, increase the rate of metabolism. What do you infer to be the advantages gained from having attractive and skillfully prepared food?

that the boys remained in excellent health and that their body wastes contained five to six times as much of the vitamin as had been fed to them. The scientists therefore concluded that riboflavin is manufactured (probably by bacteria) in considerable quantities in the human intestines. How many of the elements of scientific method (p. 571) can you identify in this experiment?

CONSUMER BIOLOGY · 1. What different grades of canned fruits and vegetables are for sale at your grocery store? Find out from your grocer in what respects the different grades vary.

2. What dehydrated and frozen foods does your grocer sell?

3. What organs (hearts, kidneys, sweetbreads, etc.) does your butcher sell? Are these cheaper or more expensive than the cuts of muscle tissue? What are some of the cheaper cuts of beef, pork, and lamb?

APPLYING YOUR KNOWLEDGE OF BIOLOGY · 1. Why are snakes, frogs, insects, and some other animals so sluggish (inactive) when the weather is cool?

2. Do you know of any wild animals in your

What different grades of canned fruits and vegetables are for sale at your grocery? Find out from your grocer how the different grades vary

locality that hibernate? Do you know of any that do not? Can you suggest reasons why some hibernate and others do not?

3. What are the relationships between these three facts? (1) Birds are very active animals, and flying is a strenuous activity; (2) the body temperature of birds is higher than that of most animals; (3) birds eat large quantities of food in proportion to their weight.

4. All the living things that are warm-blooded are in one phylum and in two classes of that phylum. Name the phylum and the two classes.

5. Ordinarily the temperature of a human being is lowest between about three and four o'clock in the morning. Why?

6. The mayor of a city in Eire went on a hunger strike a number of years ago. He went without food for 72 days before he died, but he drank some water every day. What conclusions do you draw from these facts?

7. In high-altitude flying, aviators are supplied with exactly the quantity of oxygen that they must have. What facts about an aviator's metabolism would need to be known in determining his oxygen needs?

8. Mammals shed fur and birds molt feathers in the spring. In the fall mammals have a new growth of fur, and birds have a new growth of feathers. What are the advantages of these changes to these animals?

9. A bee that fails to get back to its hive before dark sometimes crawls into a partly open flower. There it is protected from the wind. Moreover, the temperature in the flower is

higher than that outside. Explain the higher temperature in the flower.

10. The bacteria that produce vitamins G and K in the human body, and the person in whose body they live together, furnish an example of symbiosis. (See the Index.) Can you explain this statement?

TOPICS FOR INDIVIDUAL STUDY · **1.** In a textbook on nutrition, or in a book on vitamins, such as Henry Borsook's *Vitamins: What They Are and How They Can Benefit You* (The Viking Press), find out why the body needs each of the various vitamins, what their important sources are, how much of each kind is needed, how the vitamin was discovered, and other information of this kind. Prepare a brief report supplementing what is discussed in this book, to be given before your class or your home room or as part of a school-assembly or science-club program.

EXPERIMENT · What is the effect of a change of temperature upon goldfish? Obtain two healthy goldfish. Put them in separate battery jars, each of which contains the same quantity of water. Add ice cubes to the water in one of the jars. Watch the actions of the fish in this jar as the temperature of the water becomes more and more nearly that of ice, and compare them with the actions of the other fish. Now exchange the places of the two fish and again compare their actions. Why do this (p. 571, No. 6)? How do you explain what you see?

WHY NOT BECOME A NATURALIST? · **1.** Can you find evidence of regeneration in trees and shrubs? See whether you can find places where limbs have been pruned away and the cuts are regenerating (healing). Find others where regeneration has not taken place properly. Can you determine why? Can you determine how this condition is affecting the plants?

2. How do animals use energy? On a "nature hike" watch birds, insects, mammals, frogs, and other animals to see how they use energy. For example, watch a turtle move about. Compare its activity with that of an insect or of a bird. Take careful notes of your observations.

PANEL DISCUSSION · Read the instructions for conducting panel discussions, on page 116.

Topic: The protection given the consumer by the various food and drug laws and the further protection needed.

Secure from the Department of Agriculture of Canada or the United States the latest materials relating to this topic.

BIOLOGY IN THE NEWS · **1.** Watch the daily newspapers for articles concerning the discovery of new vitamins, or new uses of vitamins already discovered, or for stories of new sources of known vitamins. Take notes on articles of this kind and others, and report on them to your class.

2. Many newspapers have columns each day in which information about foods is given. Such columns may deal with problems of diet, how to gain or lose weight, etc. Read these columns and report on them to your class.

GROUP INVESTIGATIONS · **1.** *To make a survey of the diets of the members of the class.* Every member keeps a careful record of everything that he eats and drinks for a twenty-four-hour period, and hands his record, without his name on it, to the teacher. The class then elects a committee of three students. Each member of this committee examines one third of the reports and makes a record of all the diets which do not contain all the necessary energy and non-energy foods, and which seem not to contain enough bulky foods. The committee members then combine their findings and report them to the class. Remember, however, that a diet for a single day need not satisfy all these requirements.

2. *To make a survey of the lunch-time eating habits of the students, if there is a cafeteria in your school.* The entire biology class may engage in this survey. Take notes of the kinds of foods that individual students buy. Study these records to find out what proportion of the students are buying lunches that provide all the required energy and non-energy foods. Elect a committee and have them prepare an assembly program or an article for the school paper, presenting the class findings.

Values of Average Servings of Foods[1]

[Select foods in each division which together supply the daily requirements (footnote 2). From the facts shown here, do you think that your own daily diet is adequate?]

NAME OF FOOD	AMOUNT OF ONE SERVING[2]			NUTRITIVE VALUE Per cent of minimum daily allowance for adults[3]									ENERGY VALUE	FIBER[4]
	Measure	Weight		Protein	Calcium	Phosphorus	Iron	Vitamin A	Thiamine	Riboflavin	Niacin	Ascorbic Acid	Total Calories	
MILK AND MILK PRODUCTS		Oz	Gm											
Milk, fresh, whole	½ pint	8.7	244	12	38	30	2	7	8	20	3	0	168	—
Butter	1 tablespoon	.5	14	0	0	0	0	12	0	0	0	0	102	—
Cheese, American (or Cheddar)	1¼ × 1 × 1 in.	.7	20	7	23	16	2	8	1	5	0	0	79	—
Ice cream, vanilla	⅓ pint	4.8	134	7	17	16	11	16	6	11	2	0	279	—
CEREALS AND BREADS														
Cornmeal, yellow	¾ cup, cooked	1.0	28	3	0	5	3	2	4	1	3	0	100	+
Macaroni	¾ cup, cooked	1.0	28	5	1	5	3	0	4	1	6	0	102	+
Oatmeal	¾ cup, cooked	1.0	28	6	2	14	15	0	17	2	3	0	111	+
Rice, white	¾ cup, steamed	1.0	28	3	0	4	2	0	1	0	14	*	98	+
Bread, white, enriched	2 slices	1.8	50	6	4	4	9	*	12	4	11	0	131	+
Bread, whole wheat	2 slices	2.1	60	8	5	14	18	*	13	5	17	0	158	+
MEAT, POULTRY, FISH, EGGS														
Beef, lean	3 × 2 × ¾ in., broiled	3.5	100	28	2	28	50	1	15	11	45	0	194	—
Veal cutlet	3 × 2 × ¾ in., broiled	3.5	100	27	2	28	29	0	18	13	63	*	176	—
Liver, calf	4 × 2 × ½ in., broiled	3.2	90	24	1	45	109	608	36	149	162	*	122	—
Lamb chop	1 chop, broiled	3.0	85	22	1	22	23	0	17	11	42	0	195	—
Bacon	4 small slices, broiled	2.0	57	7	1	8	5	0	11	4	14	*	357	—
Pork chop, lean	1 chop, broiled	3.2	91	23	1	22	20	0	120	11	50	*	213	—
Chicken	3¾ × 2 × ½ in., roasted	3.5	100	30	2	29	19	*	11	9	86	*	149	—
Oysters	⅓ cup	3.5	100	14	9	23	71	5	20	11	10	*	81	—
Eggs, whole	2	3.5	100	18	7	28	27	25	15	18	1	0	158	—
VEGETABLES														
Asparagus, green	6 stalks	3.5	100	3	3	8	9	23	18	6	7	133	27	++
Beans, green, string, fresh	¾ cup cuts, cooked	3.5	100	3	9	6	11	38	8	6	5	83	43	++
Beans, green, string, canned	⅔ cup	3.5	100	1	4	3	14	25	3	3	3	13	19	+
Beans, navy, dried	½ cup, cooked	1.2	35	12	7	22	36	0	18	6	5	0	123	++
Beets	⅔ cup cubes, cooked	3.5	100	2	4	6	10	0	3	3	5	50	45	++
Broccoli	¾ cup, cooked	3.5	100	5	17	10	14	225	9	12	10	416	37	++
Cabbage	1 cup, chopped	3.5	100	2	6	4	4	0	8	3	3	200	29	++
Carrots	⅔ cup cubes, cooked	3.5	100	2	6	5	7	250	7	3	5	20	45	++
Cauliflower	¾ cup, cooked	3.5	100	3	3	10	11	1	15	6	6	250	32	++
Celery	2 hearts	3.5	100	2	7	5	5	0	3	2	2	17	22	++
Corn, yellow, canned	½ cup	4.0	113	3	1	8	5	5	2	3	8	17	77	+
Lettuce, head	¼ small head	1.8	50	1	2	2	3	1	4	1	1	13	9	+
Onions	2 small	3.5	100	2	4	6	5	0	3	1	1	50	49	++
Peas, canned	⅔ cup	3.5	100	5	3	9	18	20	13	5	15	37	70	++
Potatoes, white	1 small	3.5	100	3	2	8	7	1	10	3	11	40	85	+
Spinach, fresh	½ cup, cooked	3.5	100	3	**	7	34	450	10	13	7	167	25	++
Sweet potatoes	1 small	3.5	100	3	4	7	8	125	10	4	8	50	125	++
Tomatoes, fresh	1 small	3.5	100	1	2	4	6	25	8	2	6	73	23	+
Tomatoes, canned	½ cup scant	3.5	100	1	2	4	6	23	7	2	6	50	22	+
Turnips, white	⅔ cup cubes, cooked	3.5	100	2	5	5	5	0	5	3	6	100	34	++
FRUITS														
Apples	1 medium	3.5	100	0	1	1	3	2	3	1	2	20	65	++
Bananas	1 medium	3.5	100	2	1	4	6	9	5	4	6	33	99	+
Grapefruit juice, canned	½ cup scant	3.5	100	1	2	2	3	0	4	2	2	140	52	*
Oranges	1 medium	5.3	150	2	7	5	6	7	12	2	3	217	76	++
Orange juice, canned	½ cup scant	3.5	100	1	4	3	4	3	7	2	2	140	55	*
Peaches, canned	1 half with syrup	3.5	100	1	1	2	4	11	1	1	7	13	76	+
Pears, canned	2 halves with syrup	3.5	100	0	1	1	2	0	1	1	1	7	76	++
Pineapple, canned	1 slice with syrup	3.5	100	1	4	1	6	2	7	1	2	30	102	+
OILS AND SPREADS														
Margarine, vitamin A added	1 tablespoon	.5	13	0	0	0	0	6	*	*	*	*	95	—

[1]Courtesy of General Foods Corporation.

[2]Amount of serving gives measure of food as prepared, and weight of the raw edible portion required per serving. Exception: with dishes like cocoa, ice cream, bread, bran muffins, cake, fudge, pudding, etc. weight is given for the made product, not the raw ingredients.

[3]The following are the minimum daily requirement standards for an average adult as set up by the Federal Food and Drug Administration (with standards for protein and niacin added in line with present nutrition practice):

Protein, 70.00 gm; Calcium, 0.75 gm (750 mg); Phosphorus, 0.75 gm (750 mg); Iron, 0.01 gm (10 mg); Vitamin A, 4000 units; Thiamine (B_1), 1 mg (333 units); Riboflavin (B_2, or G), 2 mg; Niacin, 10 mg; Ascorbic Acid (C), 30 mg.

Vitamin D is not listed on the Food Chart, since only a few foods are good sources of this vitamin. These foods include liver of all kinds, milk, butter, eggs, and fish that is high in body-oil content.

[4]*Key to symbols used in chart* · Ratings for fiber are relative: — indicates little or none; +, some; ++, a good source; +++, an excellent source. 0 indicates no detectable amount. * indicates value not determined. ** indicates calcium not nutritionally available.

10

HOW FOOD IS USED BY LIVING THINGS

1. How Are Foods Made Ready for Use by Living Things?

It is generally believed that the earliest people on the earth lived in the warmer regions. They had to live where the climate was warm because they wore no clothing and did not know how to make and control fire. In the colder regions there was abundant fuel. This probably would have enabled them to survive there if they had known how to use it. But until man had discovered how to change into heat the energy stored in wood and coal, these fuels were of no more use to him than rocks.

If plants and animals could not change foods by digesting them, no carbohydrate, fat, or protein would be of any more use to them than were wood and coal to primitive man. To illustrate, the white of an egg consists almost entirely of protein. Yet this protein, just as it is, can neither replace the proteins in your body nor supply you with energy which would enable you to keep warm, move, or carry on respiration, blood circulation, or other vital processes. There are two reasons why it cannot: (1) The egg protein is different from any protein in your body. (2) There is no way by which the egg white can get to your body cells, because it does not dissolve in water, and hence it cannot be carried by your blood.

Even if the egg white could in some way get to your body cells, they could not do anything with it. It would first have to be digested—that is, it would have to be changed by digestive processes into simpler substances that would dissolve in water—before the protoplasm of the cells could make use of it (illustration, p. 228).

CHEMICAL AND PHYSICAL CHANGES IN DIGESTION · Digestion in a plant or an animal consists in a series of chemical processes. These processes produce chemical changes.[1] By these changes (1) carbohydrates are broken down (changed) into simple sugars, (2) proteins are changed into amino acids, and (3) fats are made into fatty acids and glycerin (glycerol[2]). These simpler compounds dissolve readily in the blood or the sap, and are carried by it to every cell. Also, they can be used by the protoplasm of the cells for building more protoplasm and for supplying energy in the form of heat, movement, etc.

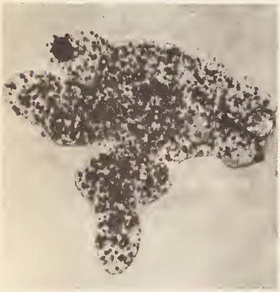
Mechanical processes that produce physical changes[1] are constantly going on, along with the chemical processes of digestion. These mechanical processes include (1) chewing and grinding, which make the food particles smaller, and (2) diffusion, kneading, and chewing, which mix the digestive juices more thoroughly with the food. All these processes function in causing digestion to be carried on more rapidly and completely than it otherwise would be.

ENZYMES · [E]Digestion in all plants and animals is brought about by enzymes, or ferments. Enzymes are complex organic com-

[1]Page 64. [2]*Glycerol* (glĭs′ĕr ŏl).

Martin Johnson

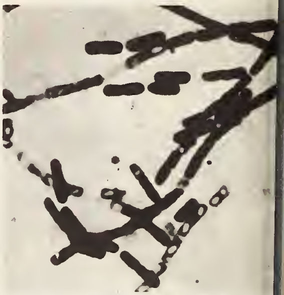
Ameba



Francis E. Lloyd (McGill), from University Film

EThe needs of a one-celled organism with respect to food might seem to be entirely different from those of a large mammal's body, of your own, or of a plant leaf. Yet they are not. PEvery living cell, whether it is a one-celled organism or one of the billions of cells in a tree or a large mammal, must have its own supplies of food and oxygen, and must be able to get rid of its wastes. Can you explain why this last statement is a biological principle?

Bacteria



Francis E. Lloyd (McGill), from University Film

pounds. Different ones take part in various life processes, but here we are interested only in the part that they play in digestion. Enzymes are specific in their actions. This statement means (1) that each enzyme affects the digestion of only a certain food, and (2) that each plant enzyme is different from the corresponding enzyme that digests the same kind of food in animals. For example, the enzyme (diastase[1]) that takes part in the digestion of starch in a plant will not affect the digestion of anything but starch, and it is different from the enzyme (ptyalin[2]) that takes part in the digestion of starch in animals.

EEnzymes do not themselves combine with the food. They merely stimulate and hasten its digestion. Moreover, they are not used up in the digestive processes, but can cause these processes to continue as long as any food remains to be digested.

[1]*Diastase* (dī′*á* stās).

[2]*Ptyalin* (tī′*á* lĭn).

DIGESTION IN PLANTS · Plants without chlorophyll (bacteria, molds, and other fungi) can neither make food, as green plants can, nor ingest food in pieces or masses and then digest it, as most animals do. Instead, they must absorb their food in liquid form. In order to do this, they must first happen to be in a substance, such as blood or milk, or upon a substance, such as meat or fruit, that they can use as food. Enzymes made inside their cells pass outside to the food and digest it. The digested food then passes back into the cells by osmosis.[1]

Parasitic bacteria, such as disease germs, feed in this same way upon living tissues. Thus they often cause the tissues to become sore and inflamed, as in cases of appendicitis and sore throat. Saprophytic[2] bacteria, molds, and other fungi consume humus and other organic materials in this same way. Thus they bring about decay.

If you put some starch, protein, or fat into water and stir the water, you will find that these three energy foods are insoluble; that is, they do not dissolve. Hence, whenever a plant needs any of the food which it has stored as starch, protein, or fat in any of its structures, it must first change these insoluble substances to soluble substances. This it does by processes of digestion.

In the simpler many-celled plants the digested foods pass from cell to cell chiefly by osmosis. In the higher plants the digested foods dissolve in the plant sap and are carried by it to all the living parts of the plant.[3]

No plants, not even the highest forms (the flowering plants[4]), have digestive organs or organ systems. In every plant digestion is carried on by each individual cell.

DIGESTIVE ORGANS OF ANIMALS · **Of lower invertebrates.** Any part of an ameba's body can serve as a mouth for ingesting food. Likewise, any part of it can serve as an anus[5] for getting rid of undigested materials and body wastes

An ameba is a predator, as well as a scavenger. Hence we should expect it to prey upon smaller one-celled plants and animals. But we should hardly expect it to be able to feed upon a strand of alga (illustration, p. 555). Nevertheless it can. The tiny mass of protoplasm slowly flows over and around a section of the strand. The ameba does not, however, need to remain attached to the strand until it has digested what it has engulfed. Instead, it "bites off" the strand at the point where the strand enters its body and also at the point where it leaves. Then it moves off with the length of alga inside it.

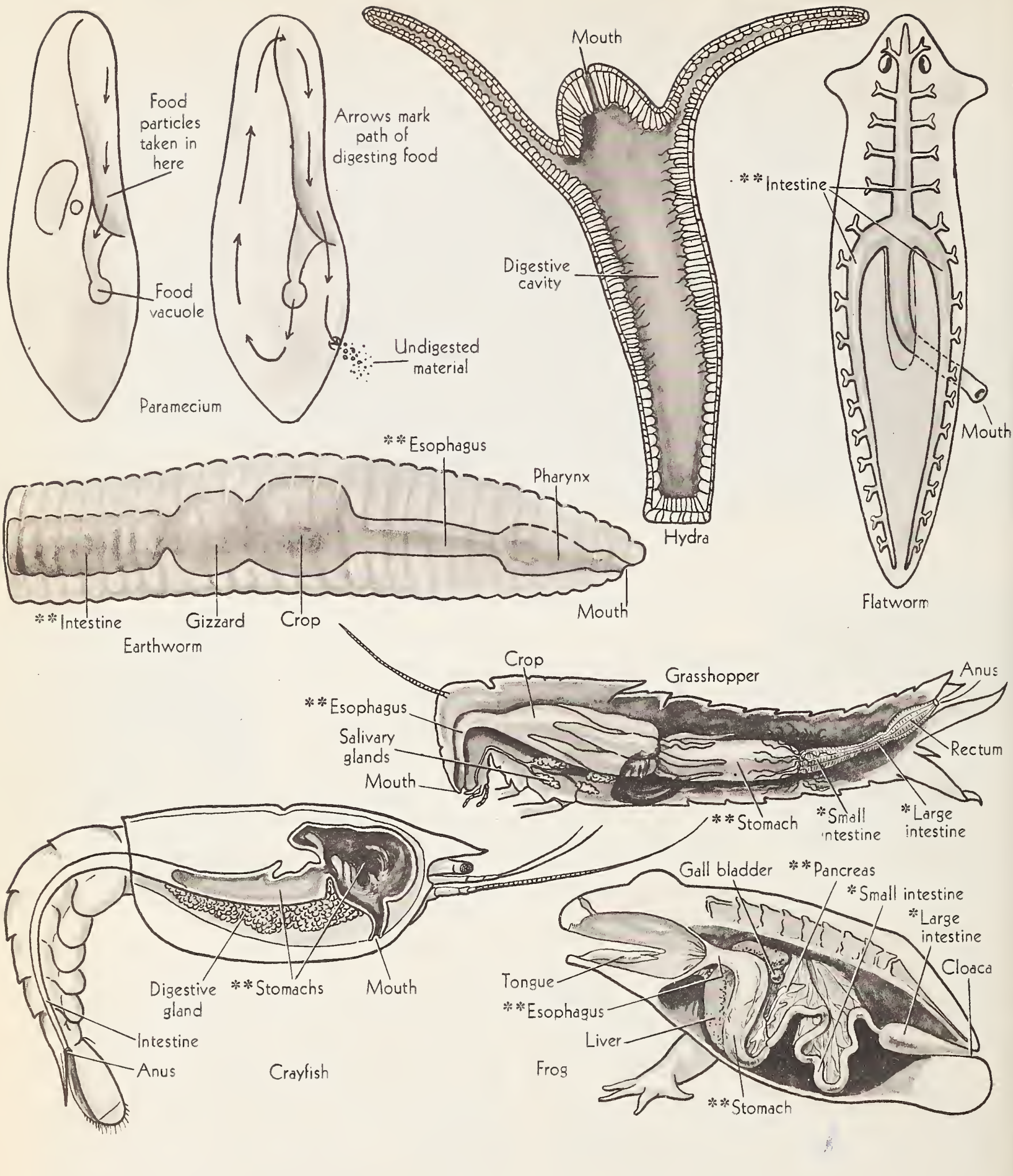
Sometimes an ameba does not capture another whole ameba, but only a part of one. The noted American biologist Jennings[6] tells about having watched through a microscope a large ameba pursuing a smaller one. Finally the larger one succeeded in flowing around and in "biting off" a portion of the smaller one. However, in this case, before the smaller piece died, it managed to break out of its predator's body and thus to make its escape.

Of course no protozoan could have digestive structures in its single-celled body. Nevertheless one certain part of a paramecium serves as a mouth. Moreover, the food, as it is being digested, follows a certain definite path through the animal's body, and the undigested wastes pass out at a certain point (illustration, p. 230). In these respects digestion in a paramecium is similar to that in higher animals.

[1]Footnote, p. 151.
[2]Page 557.
[3]Page 161.
[4]Page 562–564.

[5]*Anus* (ā′nŭs): the opening at the posterior (rear) end of the food tube.

[6]*Jennings* (jĕn′ĭngz). Born, 1877; still living.



How does this picture illustrate the following principle? In general, the higher an animal is in the scale of life, the greater is the division of labor in its body

Animals such as the hydra and the flatworm are too simple in structure to have complex digestive systems. Nevertheless they have digestive structures (illustration p. 230). In each of these structures digestive processes are carried on which, in higher animals, are performed separately in several or many organs.

Of higher invertebrates and vertebrates. The illustration on page 230 shows five animals, each of which has an alimentary[1] canal.* An alimentary canal is a food tube, or digestive system, made up of passages and chambers through all of which the food must pass. Each digestive organ performs one or more functions in the total digestive process.

As the illustration indicates, there are many variations in the digestive systems of different animals. Yet those of the vertebrates, and of invertebrates as far down in the scale of life as the earthworm,[2] include the following parts, or divisions:

1. A mouth. The chief function of a mouth is to admit food. The mouths of animals that chew their food are equipped with various structures that directly or indirectly take part in the processes of digestion. These structures include (1) teeth, for holding, cutting, tearing, and grinding the food; (2) structures (glands) that furnish saliva,**[3] a fluid which contains an enzyme that digests starch; and (3) a tongue, which mixes the saliva with the food and keeps the food where the teeth can act upon it.

2. An esophagus,[4] or gullet.** The esophagus is a muscular tube connecting the mouth with the crop or the stomach. It produces no enzymes and hence does not take part in the digestion of food.

3. A crop or a stomach, or both. These organs serve chiefly for the storage of food until it can be digested. Digestion takes place in them, however, to a varying extent. In crops digestion is carried on not by enzymes produced in the crops, but by bacteria of decay that are swallowed along with the food.

In the first stomach**[5] of an animal, such as the animals shown on page 233, considerable digestion is likewise brought about by bacteria. In the other stomachs of one of these animals and in the single stomachs of other vertebrates, digestion is carried on almost entirely by enzymes.

The gizzard of an animal that possesses one takes the place of teeth and tongue in grinding and mixing the food. This organ has strong muscular walls, which compress and knead the food as it passes through. You may have seen chickens "eat" bits of fine gravel or even small pieces of glass or chinaware. Similarly, you may have observed tame canaries swallowing grains of sand or breaking off and swallowing tiny bits of the endoskeletons[6] of cuttlefish. These hard objects lodge in the gizzard, where they help in grinding the food. The stomachs of crayfish and of some other arthropods[7] contain structures somewhat like teeth, which grind the food.

4. The intestines. Animals such as the earthworm and the crayfish have a simple, straight intestine (illustration, p. 230). The intestines of most animals, however, are more or less coiled. The higher vertebrates have a small and a large intestine. The former leads into the latter (illustration, p. 230). In the higher animals most of the digestion takes place in the intestines.

DIGESTIVE GLANDS · [E]An understanding of digestion requires some knowledge of glands. A gland is a structure that secretes,**[8] or

[1]*Alimentary* (ăl ĭ mĕn′tȧ rĭ). [2]Pages 512 and 521. [3]*Saliva* (sȧ lī′vȧ). [4]*Esophagus* (ē sŏf′ȧ gŭs). [5]*Stomach* (stŭm′ăk). [6]Page 536. [7]Page 527. [8]*Secrete* (sē krēt′).

manufactures, special chemical substances necessary to various bodily processes. Glands are of two kinds, the duct glands and the ductless, or endocrine,*[1] glands. The duct glands have tubes, called ducts, through which their secretions,**[2] or manufactured substances, pass. The endocrine glands have no tubes. Their secretions, called hormones,**[3] pass through their walls into the blood stream, which carries them to all parts of the body.

The glands whose secretions bring about directly the chemical changes of human digestion are all duct glands. They are of two types: One type includes countless microscopic, tube-like or goblet-shaped structures in the walls of the alimentary canal. The other includes eight large organs, namely, three pairs of salivary[6] glands, the liver,**[7] and the pancreas**[8] (illustration, p. 235). These large glands are outside the digestive system, but they pour their secretions through ducts into it.

The endocrine glands do not take part directly in digestion, but their hormones indirectly control it, as, in fact, they control all the bodily processes.[9] More is said about endocrine glands in other parts of the book.[10]

2. How Does Digestion Take Place in a Typical Mammal?

The digestive processes of all the vertebrates are much alike. Hence the digestive processes of man will be described as typical of those of all vertebrates.

DIGESTION IN A MAMMAL[4] · **In the mouth.** If you have ever watched a dog eat, you have probably noticed that it swallows whole all the pieces of food that are not too large to swallow. The only chewing it does is what is necessary in order to cut food into pieces small enough to swallow. The dog does not need to chew its food much, because practically no digestion takes place in its mouth. An important digestive process, however, is carried on in the human mouth. Therefore we must chew our food considerably before swallowing it.

We have front teeth (incisors[5]), similar to those of the dog, for biting off pieces of food (illustration, p. 234). We have a tooth at each side (a canine), for holding, cutting, and tearing. The canines are somewhat like the corresponding teeth of the dog, though much smaller. Also, we have broad, flat teeth (molars), for grinding, in place of the dog's shearing teeth.

The salivary glands pour saliva into the mouth at different points (illustration, p. 235). Also, microscopic glands in enormous numbers, scattered throughout the mucous membrane that lines the mouth and the rest of the alimentary canal, secrete mucus.**[11] This is a slippery fluid that causes the food to slide readily through the alimentary canal and also makes it more completely liquid. The fluid in the mouth, which is usually called saliva, is a mixture of saliva from the salivary glands and mucus from the mucous glands.

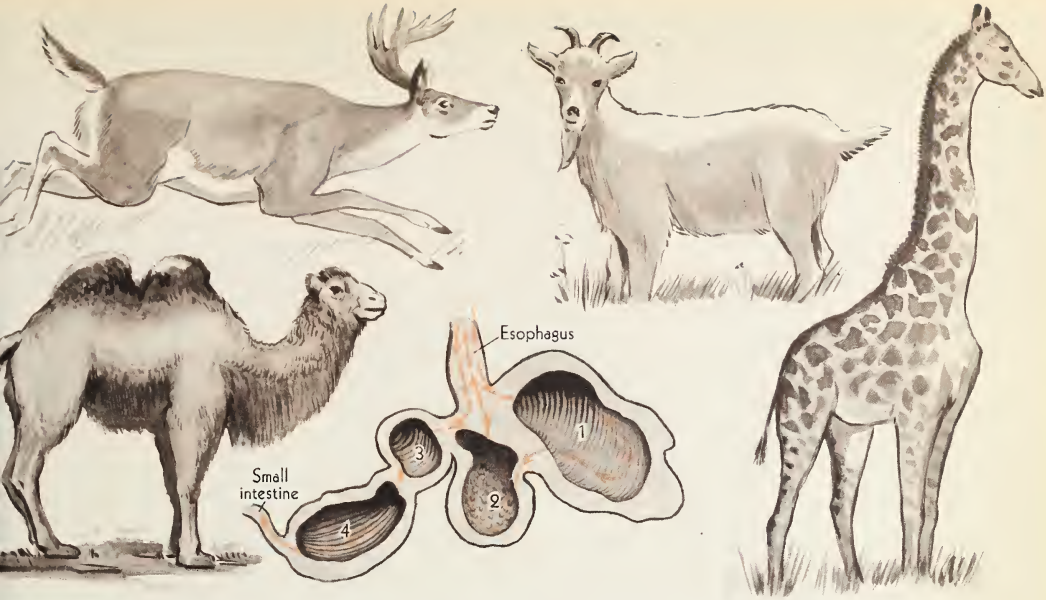
While the food is being chewed and thus

[1]*Endocrine* (ĕn′dō krĭn). [2]*Secretion* (sē krē′shŭn). [3]*Hormone* (hôr′mōn). [4]Page 547. [5]*Incisor* (ĭn sī′zẽr).

[6]*Salivary* (săl′ĭ vẽr ĭ). [7]*Liver* (lĭv′ẽr).
[8]*Pancreas* (păn′krē ăs).

[9]Like vitamins and enzymes, hormones are *catalysts* (kăt′*ȧ*lĭsts). A catalyst is a substance which causes a chemical change to take place more quickly than it otherwise would, but which itself is not changed or "used up" in the process.

[10]Pages 290–293. [11]*Mucus* (mū′kŭs).



The stomach of a typical mammal has one chamber. The stomachs of the "cud-chewing" mammals shown here consist of four chambers. The arrows show the path followed by the food. **Topic for Individual Study:** How the stomachs of ruminants function. These animals, which do not have effective defenses against big predators, are able to ingest great quantities of grass quickly and then later, while resting, chew it. How are the chances of the animal's survival thus made greater?

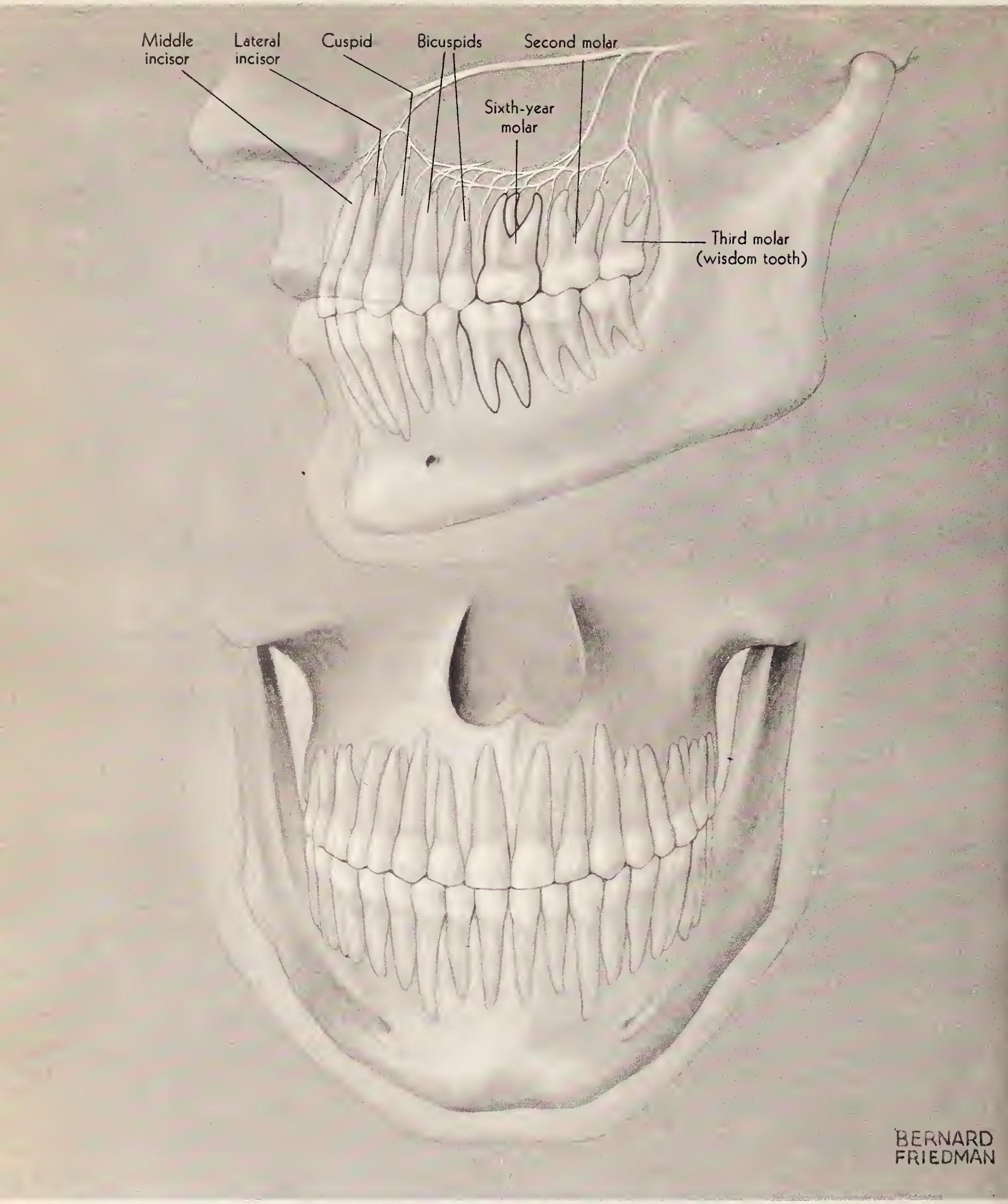
ground into small bits, it is being mixed with the saliva by the action of the tongue and of the cheek muscles. The saliva makes the food soft and moist enough so that we are able to swallow it. The enzyme in the saliva digests starch, but it does not affect either protein or fat. It changes starch, which is not soluble in water, to sugar, which is. You have probably observed that bread becomes sweeter to the taste as you chew it.

The esophagus. After solid food has been swallowed, about eight seconds are required for it to pass through the esophagus to the stomach. The act of swallowing starts a process, called peristalsis,[1] which forces the food toward the stomach (illustration, p. 239). Peristalsis results chiefly from the action of ring-like muscles in the walls of the esophagus, though other muscles, running lengthwise, assist.

Peristalsis takes place somewhat like this: Suppose that you were to put a marble into the top of a rubber tube a little smaller in diameter than the marble. Suppose then that you were to close your fingers around the tube immediately above the marble, and were to force the marble, at the rate of about an inch and a quarter per second, through the tube.

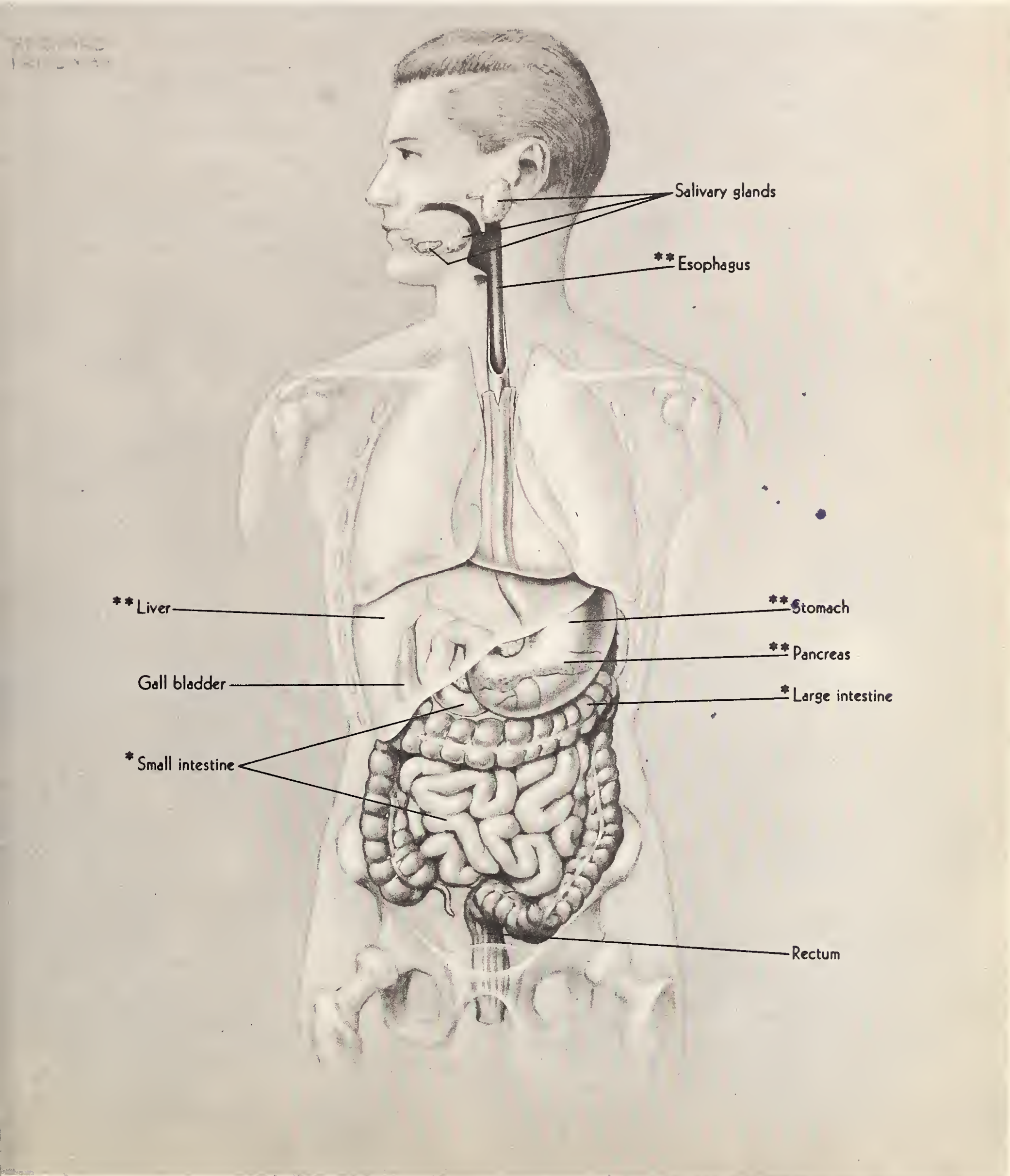
In somewhat the same way peristalsis takes place in the esophagus: The ring of muscles

[1] *Peristalsis* (pĕr ĭ stăl′sĭs).



The types of human teeth · Topics for Individual Study: There are thirty-two teeth in a complete set of an adult, but only twenty in that of a child. A young child lacks the twelve molars. Why are "baby teeth" called "deciduous teeth"? What is the order in which the different teeth appear? (Consult your family dentist or a textbook of physiology)

[E]The organ-system of digestion in man includes the organs which make up the alimentary canal, together with the salivary glands, the pancreas, and the liver. How does the biological definition of *canal* differ from the common one? (Consult a dictionary)



directly above the food contracts (draws together) while that directly below it relaxes (becomes slack). Thus the food is pushed slightly downward. At once the rings of muscles now directly above and below the food contract and relax, respectively, as the preceding ones did. The muscles lower down similarly continue the process in turn, as the food reaches them, forcing it steadily toward the stomach. The passage of this movement along the esophagus is called a peristaltic[1] wave (illustration, p. 239).

Peristalsis takes place not only in the esophagus, but also in the stomach and the intestines. It is entirely separate, however, in each of these digestive organs.

In the stomach. The mucous membrane that forms the inside lining of the stomach contains millions of minute glands. They are like tiny tubes, side by side. Different kinds of cells in the inside walls of these glands produce the substances that make up the gastric**[2] juice. These substances include hydrochloric acid and two important enzymes, whose functions will be described later.

Hydrochloric acid does not digest food, as the enzymes do. Yet it performs important functions, including these: (1) It acts as a germicide,—that is, it kills most of the bacteria that are always in whatever we eat,—and thus it halts the decay of the food. (2) It starts and hastens the chemical action of the enzyme which acts upon proteins. (3) It causes the stomach movements to start. (4) When enough of it has been poured into the stomach by the glands, it acts upon the ring-like muscles that close the lower end of the stomach. It causes them to open every few seconds and each time to allow a small amount of the partly digested food (chyme[3]) to pass into the small intestine. (5) It causes other digestive organs, especially the liver and the pancreas, to begin their work.

One enzyme in the gastric juice starts the digestion of proteins in the stomach. The second one aids in the digestion of milk. This is an important chemical action, especially in young mammals, whose only food is milk. There is almost no digestion of fat in the stomach. What does occur there is probably only the digestion of butterfat, in milk.

The movements of the stomach include kneading movements and peristalsis. The kneading movements mix the food with the gastric juice. Peristaltic movements keep the food moving toward the lower end of the stomach, where it becomes half liquid. The movements of the upper part of the stomach are much less vigorous than those in the lower part. Consequently the gastric juice is mixed with the contents of the upper part slowly. When the hydrochloric acid reaches all parts of the food, it not only kills bacteria, but also stops the digestion of starch, which began in the mouth.

In the small intestine. Soon after the partly digested food (chyme) enters the small intestine, it is mixed with the secretions produced by two duct glands, the liver and the pancreas (illustration, p. 238). The liver makes a fluid called bile**[4] or gall. The bile flows from the liver into the gall bladder and thence into the small intestine.

Bile consists chiefly of waste materials from the blood. It contains no enzymes. Hence it does not directly carry on any chemical processes of digestion. It does, however, function indirectly, thus: (1) It stimulates the action of the pancreatic[5] juice, that is, the fluid from the pancreas. (2) It breaks up fat into very small drops and thus causes it to be much more readily and quickly digested by

[1]*Peristaltic* (pĕr ĭ stăl'tĭk).
[2]*Gastric* (găs'trĭk): pertaining to the stomach.
[3]*Chyme* (kīm).
[4]*Bile* (bīl).
[5]*Pancreatic* (păng krē ăt'ĭk).

one of the enzymes from the pancreas. (3) It enables the body to absorb greater quantities of digested fat than it otherwise could. (4) It is believed to cause the absorption of vitamin K[1] into the blood.

The pancreatic fluid contains several enzymes. One completes the digestion of some starches by changing them into simple sugars. Another completes the digestion of some proteins by changing them into amino acids. A third completes the digestion of some fats by changing them into glycerin and fatty acids.

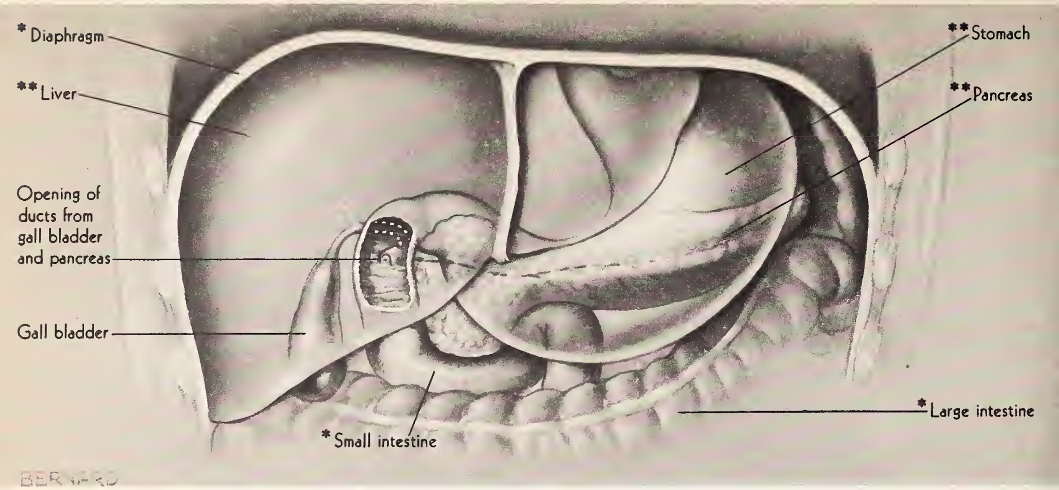
Millions of minute duct glands, in the walls of the small intestine, secrete intestinal juice. This contains enzymes that complete the digestion of the starches, proteins, and fats that are not completely digested by the pancreatic enzymes.

Muscles in the walls of the small intestine produce two actions, peristalsis and a mixing action (illustration, p. 239). The peristalsis occurs only at intervals of about thirty minutes or longer. After moving the food onward a few inches, it ceases. When peristalsis ceases, the mixing action begins.

To get an idea of the mixing action, imagine two people with their hands around a rubber hose, one with a hand between the two hands of the other. Imagine that one person squeezes the hose with both hands while the other relaxes both hands, and that the

[1]Page 208.

Many conditions cause the digestive glands to vary the amounts of their secretions. These conditions include the odor and sight of food, the degree of hunger, the thought of food, anger, disgust, and sadness. Meal-times should be made as pleasant as possible. What factors in this picture stimulate healthy digestion?



Where the bile and the pancreatic juice enter the small intestine.
How does this illustration supplement that on page 235?

second person then squeezes the hose while the first relaxes his grip.

In somewhat the same way the mixing action of the intestine take place: Muscles about an inch apart along the intestine contract at the same time. After a few seconds these muscles relax, and similar ones between them contract. Perhaps a third set acts in the same way. Then the cycle is repeated.

The mixing action hastens and completes digestion by mixing the enzymes more thoroughly with the food. Also, it presses the digested foods against the walls of the intestine. Thus it hastens and increases their absorption into the blood.

The inside lining of the small intestine has, along its entire length, great numbers of uneven, cross-wise folds (illustration, p. 240). The inner surfaces of these folds are covered with millions of minute, finger-like absorbing organs, called *villi*[1] (illustration, p. 240). The villi cause the absorption of the digested food and of dissolved mineral compounds and vitamins to be more complete and rapid than it otherwise would be. They do this (1) by delaying the progress of the food materials through the intestine and thus providing more time for them to be absorbed, and (2) by increasing the area of the absorbing surface greatly—in fact, in some places, as much as fifteen times.

By the time the digested material reaches the large intestine, most of the digested foods have been absorbed from it. The material is still, however, in a highly watery condition.

In the large intestine. At least seventy-five kinds of bacteria inhabit the small and large intestines, and the total population of bacteria in these organs always runs into the billions. Practically all compete with man for his digested food. The life habits of some of these bacteria make them harmful to their host, and those of others make them useful to him; but those of most of them do not affect him in any way.[2]

Certain species of bacteria that live in the

[1] *Villi* (vĭl′ī); singular, *villus* (vĭl′ŭs).

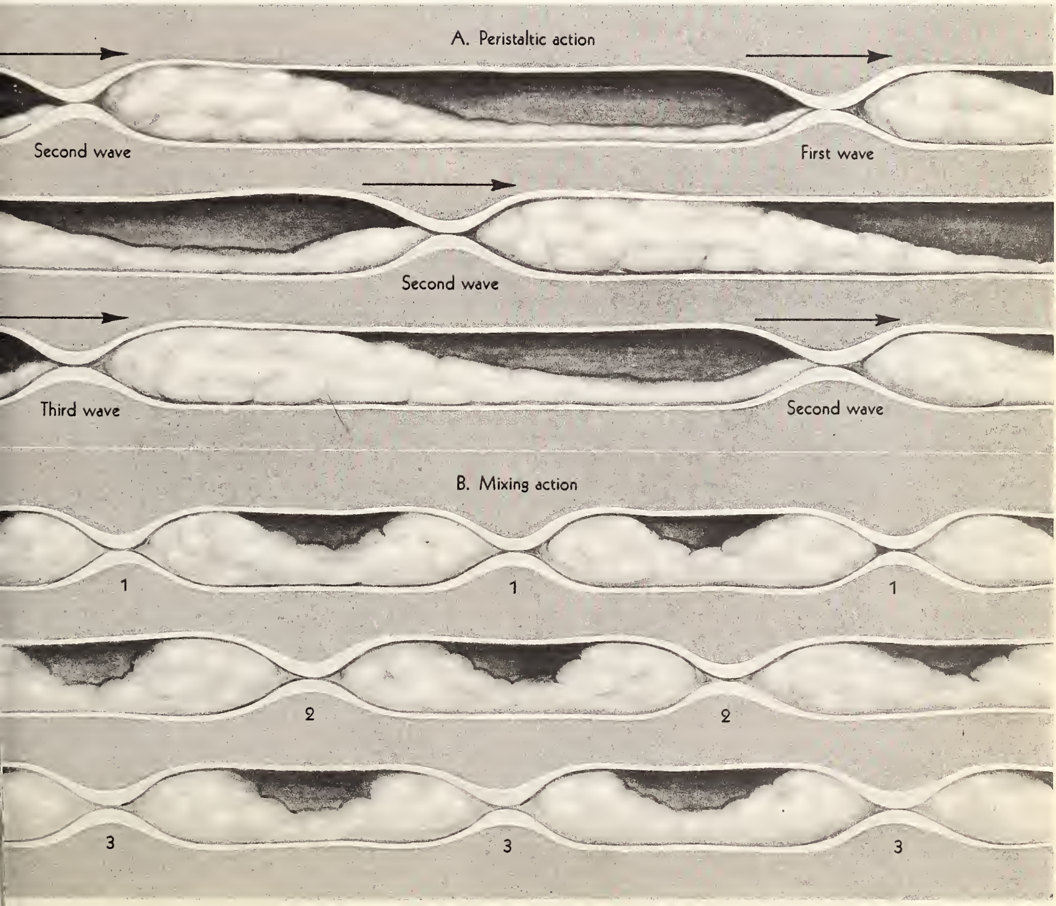
[2] Page 280.

large intestine benefit their host by acting upon cellulose. Cellulose is not affected to any great extent by enzymes. Hence it passes into the large intestine practically undigested. There these bacteria feed upon it and in doing so change small quantities of it into simple substances that are of great value to the body.

Certain other bacteria, which live in both the large and the small intestine, produce waste substances that are to some extent absorbed into the blood and sometimes act as poisons. How serious the effects of these substances are upon the host is not yet fully known, but probably they are rarely grave in the case of a healthy person.

As the food is slowly forced through the large intestine, most of the water in it passes by osmosis into the blood vessels of the intestinal walls. Consequently the material that finally is eliminated from the rectum is nearly solid. It consists of undigested food and other materials, billions of bacteria, waste materials in the bile, and some waste materials besides those produced by digestion.

Peristalsis (*A*) and mixing action (*B*) in the intestines. Compare these two actions, stating respects in which they are alike and those in which they are different



CONSTIPATION · Most people have one elimination of waste materials from the intestines daily. Other people have more frequent or much less frequent eliminations, and yet are healthy. A person becomes constipated only when the digestive wastes remain in his large intestine considerably longer than is normal for him.

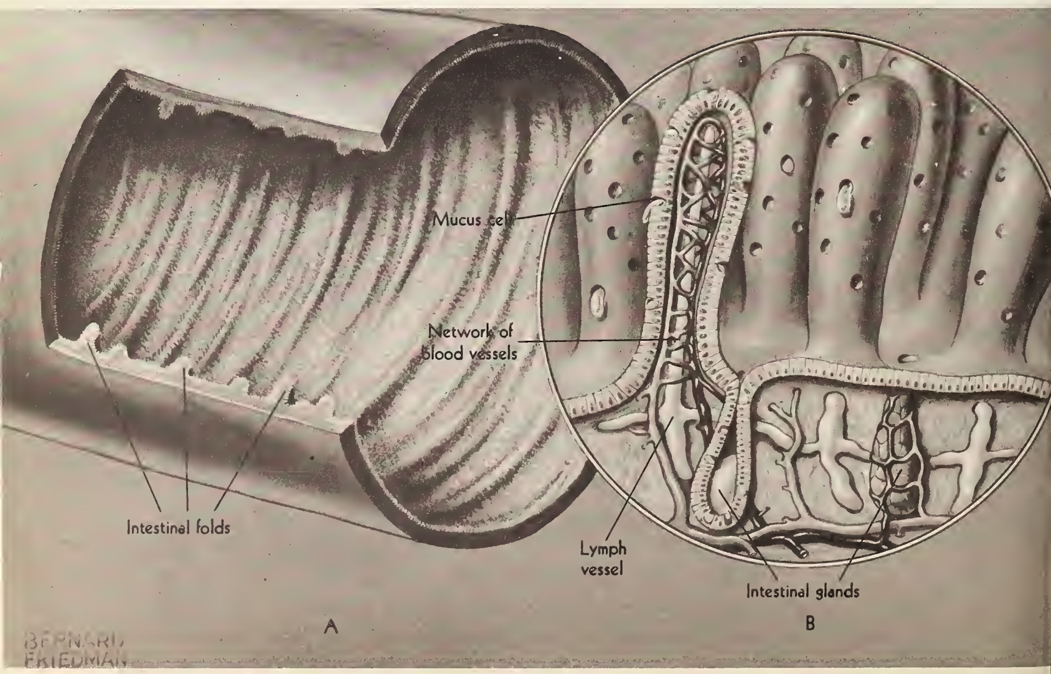
[E]Healthful ways of avoiding and correcting constipation include eating a diet that contains some bulky foods, establishing the habit of having regular eliminations, and taking exercise (illustration, p. 243). Taking laxatives is not a desirable method. It may even be dangerous, especially if the constipation is accompanied by severe and continued pain in the abdomen.[1] Such a symptom may indicate appendicitis.

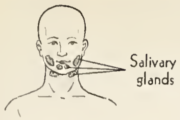
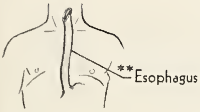
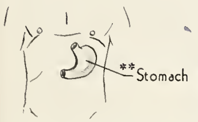
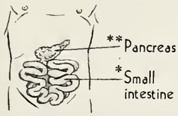
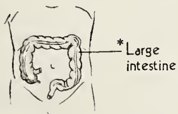
The appendix is not known to have any useful functions. Instead, it is a source of danger, since appendicitis is still the cause of thousands of deaths annually, in spite of the use of modern surgery and modern drugs. If, during an attack of appendicitis, one takes a laxative to relieve the pain and constipation, the danger of aggravating the infection is increased. The appendix may even burst and thus cause the infection to spread to other organs. In such a case the results are certain to be serious, and may be fatal.

In all cases of continued constipation, therefore, and especially in all cases of severe pain in the abdomen that persists for several hours, it is always wise to consult a physician. From the symptoms he will decide whether the appendix should be removed by surgery.

[1]*Abdomen* (ăb dō′mĕn).

A, cross-wise folds of the inside lining of the small intestine; *B*, villi. What advantage results from having glands to secrete intestinal juice and also glands to secrete mucus all along the intestine?



ORGANS	SECRETION	CHIEF FUNCTIONS
	Enzyme in saliva	Begins digestion of starches
	Mucus	Makes food slippery and more nearly liquid
		Conveys food from mouth to stomach Digestion of starch continues
	No enzymes	
	Mucus	Makes food slippery and more nearly liquid
	Gastric juice, which contains hydrochloric acid. . . .	Stimulates digestion and regulates it somewhat Stops action of bacteria
	Enzymes	Begins digestion of proteins Probably digests butter-fat Starts digestion of milk
	Mucus	Makes food slippery and more nearly liquid
	Bile	Changes fats to minute drops Stimulates action of pancreatic juice Helps body to absorb fats
	Enzymes	Changes undigested and partly digested starches to sugars Changes undigested and partly digested proteins to amino acids Changes fats to fatty acids and glycerin
	Mucus	Makes food slippery and more nearly liquid
	No enzymes	
	Bacteria	Digest cellulose
	Mucus	Makes contents move through more readily

Summary of Human Digestion · **Topics for Individual Study:** Name the enzymes produced in the mouth, stomach, pancreas, and small intestine. Match each with its function as stated in the third column

3. *How Are the Cells Supplied and Their Wastes Removed?*

Scientists believe that plants and animals lived in the oceans for ages before there were any that lived on the land. The earliest organisms were so simple in structure that either all their cells were bathed by the water or not more than one or two layers of cells were between any cell and the water. Consequently every cell could get food and the dis-

solved oxygen that it needed either directly from the water or from its neighboring cells. Every cell could get rid of wastes just as easily.

When more complex animals appeared in the oceans, most of the cells within their bodies were too far away from the water for their needs to be supplied by it. Such animals were equipped with gills or other structures which enabled them to secure oxygen and to excrete carbon dioxide. Also, they had vascular systems which brought blood as close to every cell as the ocean water had been to every cell of their more primitive ancestors. The blood carried dissolved food, oxygen, and other needed materials to all the cells. Also, it took away their wastes.

CELL PROCESSES · [E]As has already been said,[1] the processes related to metabolism go on all at the same time. These processes include (1) the passing of digested energy foods and of vitamins and hormones into each cell; (2) respiration, that is, the passage of oxygen into the cell and of carbon dioxide and surplus water out of it;[2] (3) the combustion of energy foods inside the cell; (4) assimilation,**[3] that is, the process by which the protoplasm of the cell builds new protoplasm; and (5) excretion.

Cells can secure the substances that they need only when these substances are dissolved in the liquid that immediately surrounds them or that moistens their cell membranes. This liquid is, in nearly every case, water, plant sap, blood, or lymph.[4] Carbon dioxide and other waste materials likewise dissolve in the blood, water, or other liquid that surrounds or moistens the cells.

SOURCES OF OXYGEN · Oxygen enters through the openings in the leaves and stems of land plants[5] and enters the lung cavities and other breathing structures of "air-breathing animals" as a gas, along with the rest of the air (illustration, p. 244). It is not, however, used directly as a gas. Before it can enter the internal structures of such plants and animals, it must dissolve in the moisture that covers the surfaces of the structures.

RESPIRATION AND CIRCULATION IN SIMPLE ORGANISMS · Oxygen passes into a one-celled animal or plant by osmosis. Carbon dioxide, surplus water, and other waste materials pass out of it by the same process. The movements of the organism or the movements of the liquid in which it happens to be bring it into contact with fresh supplies of oxygen and separate it from its wastes. Thus such movements serve the same purpose for a one-celled organism that a respiratory and a circulatory system do for a higher plant or animal.

RESPIRATION IN HIGHER ORGANISMS · Though respiration and circulation are merely separate parts of the great process of nutrition, it is more convenient to discuss respiration and circulation in higher organisms separately.

In plants. The organs of respiration in nearly all the higher plants are the stomata, the lenticels, and the roots. How the stomata and lenticels function in securing oxygen and in getting rid of carbon dioxide and surplus

[1]Footnote, p. 215.

[2]This process is known as *internal respiration.* In higher animals respiration includes also breathing and other processes by which the animals take in and expel air. Such processes are included in the term *external respiration.* Some biologists define respiration as the process by which energy foods are burned in the cells and by which heat and other forms of energy are released. In this book, however, that process is called combustion.

[3]*Assimilation* (ă sĭm ĭ lā′shŭn).

[4]*Lymph* (lĭmf): the fluid which surrounds the cells.

[5]Pages 153, 164.

water is explained in another part of this book.[1] Plant roots absorb chiefly oxygen that is dissolved in the soil water. Swamp and water plants that grow in mud that contains relatively little air have adaptations of structures that aid them in obtaining oxygen. For example, most of them have fibrous root systems which spread out just below the surface of the mud, where more oxygen is available than at lower levels. Water lilies, rushes, and other water plants have air-filled spaces inside their stems, from which oxygen passes by osmosis into their roots. Cypresses and some other trees that grow in swamps have stump-like "knees" or other structures that grow from the roots upward above the mud and water and that may absorb some oxygen.

In animals. Some of the Metazoa carry on respiration through their moist skins. For example, the earthworm does. Oxygen passes through its skin and into its blood, which flows through a network of minute, thin-walled tubes, called capillaries, just beneath the skin. Carbon dioxide and surplus water pass out just as readily by the same means.

[1]Pages 153, 164.

How many different ways in which these high-school girls are exercising can you identify in this picture? In addition to the benefits stated in the text, exercise prevents sagging of the stomach and other digestive organs. Can you explain why?

Eisenstaedt—Pix

Bell Telephone Laboratories

Man is called an air-breathing animal, but he is really no more an air-breathing animal than is a fish. Explain. How do you account for the facts that although both a man and a fish require oxygen, the fish will soon die if taken out of water and the man will soon drown if kept submerged in water?

The special respiratory structures of the Metazoa vary widely in form (illustration, p. 246). Yet they are all alike in having an enormous surface of thin-walled tissues. These tissues are well supplied with capillaries, into which oxygen passes and out of which carbon dioxide and water pass, by diffusion and osmosis. Most of the Metazoa have also breathing organs, which cause the air, or the water containing dissolved air, to pass over the absorbing tissues and which force out excreted carbon dioxide and water

Most animals that live submerged in water have respiratory structures that either are feathery or consist of numerous thin, plate-like tissues (illustration, p. 246). The king, or horseshoe, crab has a book-gill, similar to a spider's book-lung (illustration, p. 246).

This, as its name suggests, consists of a considerable number of separated sheets of tissue, between which the water, containing dissolved oxygen, circulates. Fish, crustaceans,[1] and many other aquatic animals have gills, made up of thin tissues (illustration, p. 246). The gills of fish have numerous fine sections (filaments[2]), somewhat like the teeth of a comb.

The so-called "air-breathing animals" include not only all that live on land, but also many that live in the ocean. Examples of these marine animals include reptiles, such as sea snakes and turtles, and mammals, such as whales and seals. Among the "air-breathing animals" are also a few, such as the larvae and pupae of mosquitoes, that live under water but get air directly through one or more tubes which they thrust above the surface (illustration, p. 313).

Air enters the body of an adult insect through breathing pores, called spiracles*[3], along the sides of its abdomen** (illustration, p. 246). These minute openings lead into a system of branching tubes, called tracheae.**[4] The tracheae admit air to all parts of the insect's body. Spiders and a few other arachnids have, in addition to tracheae, book-lungs, usually one on each side of the abdomen.

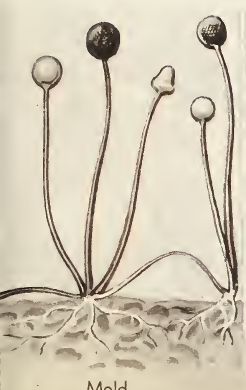
Frogs and many other amphibians are able to absorb oxygen and to excrete carbon dioxide both through their lungs and through their moist skins. The amount of respiration that they carry on through their skins, however, is relatively small. It is nevertheless great enough to enable the animals to remain alive while they are hibernating in the mud at the bottoms of ponds during the winter.

The respiration of man, as a typical mammal, will be presented later.

[1]Page 530. [2]*Filament* (fĭl'ȧ mĕnt).

[3]*Spiracle* (spī'rȧ k'l).
[4]*Tracheae* (trā'kēē); singular, *trachea* (trā'kē ȧ).

Such simple many-celled organisms as these neither need nor have special organ-systems of respiration or other processes. All their cells are near enough to the source of oxygen, food, and other necessities so that these pass from cell to cell by osmosis. Also, the waste materials from the cells pass out in the same way. **Topic for Individual Study:** Organisms that are killed by free oxygen—the anaerobic bacteria. (Consult a textbook of botany or an encyclopedia)

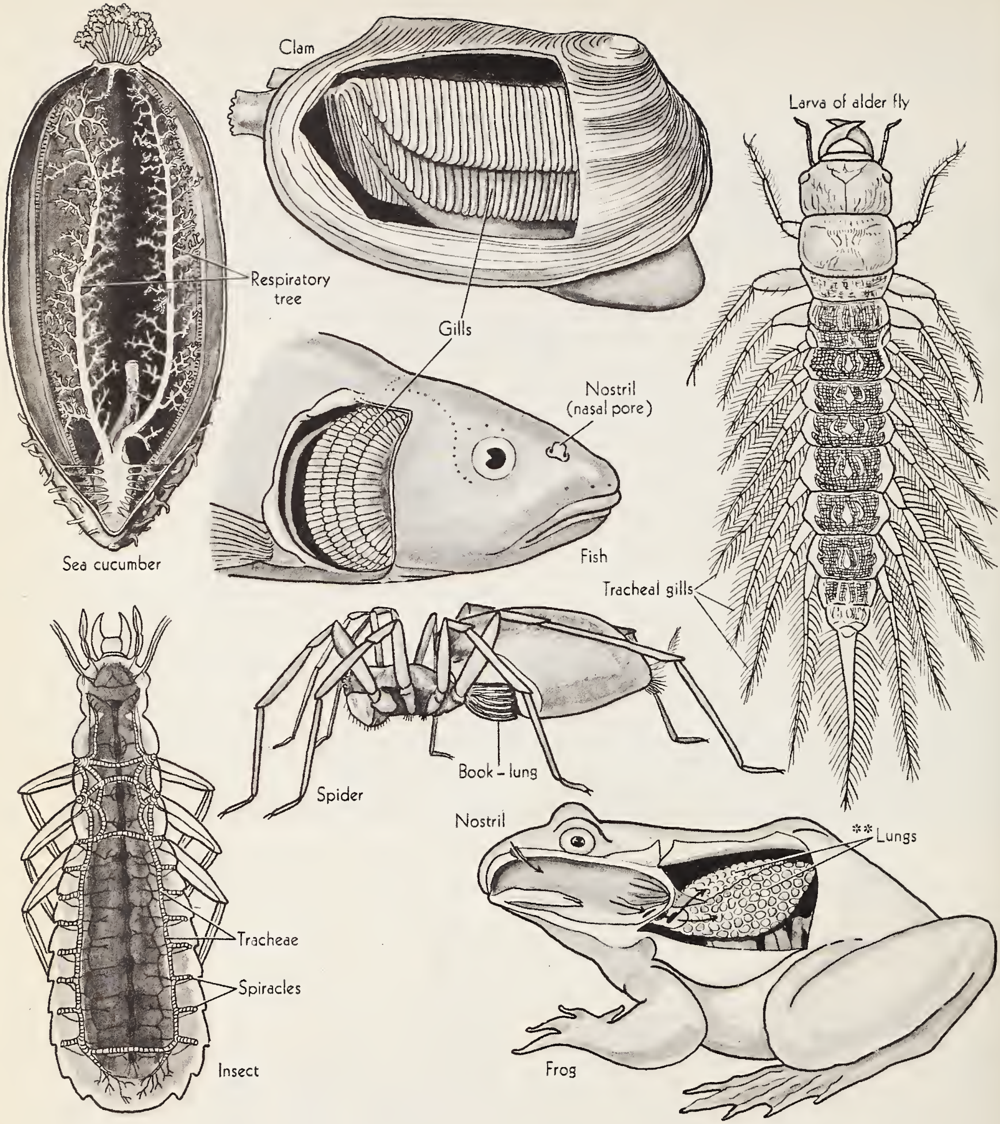


Mold

Moss

Sponge

Hydra



Examples of various organs of respiration · Why must respiratory organs have enormous surface areas of thin-walled tissues?

CIRCULATION IN HIGHER ORGANISMS · **In higher plants.** The processes by which the plant sap travels through the xylem and the phloem tubes of the fibrovascular bundles are described in another part of this book.[1]

In invertebrates. Many of the lower Metazoa have no special circulatory structures. They do not need such structures. All their cells are near enough to the sources of food, oxygen, and other necessities so that these substances pass from cell to cell by diffusion and osmosis. Also, their waste materials pass out of all the cells similarly. In the higher animals, however, organ-systems are needed for transporting necessary materials to the cells and waste materials from them. Such organ-systems consist of (1) one or more hearts, and (2) blood vessels—in most cases arteries, capillaries, and veins (illustration below). The heart or hearts force the blood through the blood vessels.

[1]Pages 159–162.

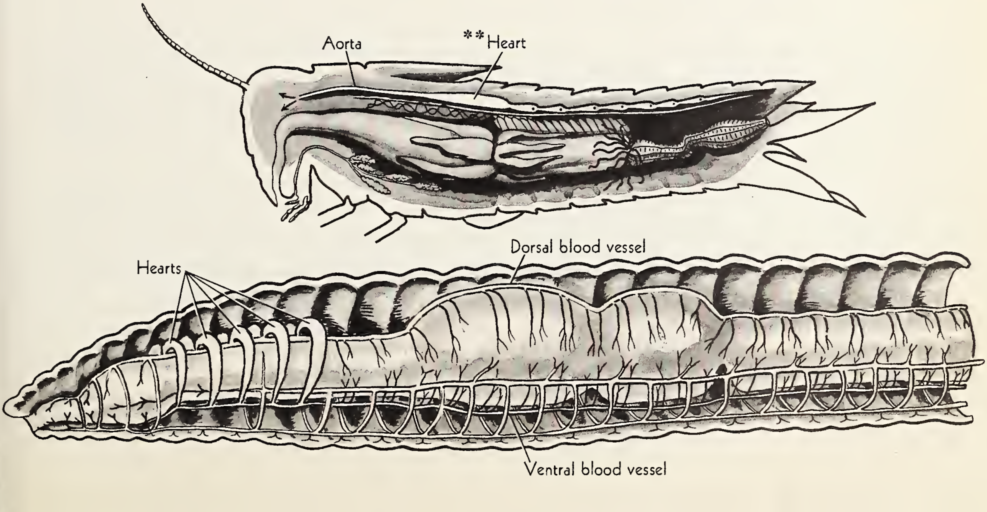
In vertebrates. As is indicated in the illustration on page 248, the heart of any vertebrate has at least one auricle*[2] and one ventricle.*[3] That of a bird or a mammal has two of each.

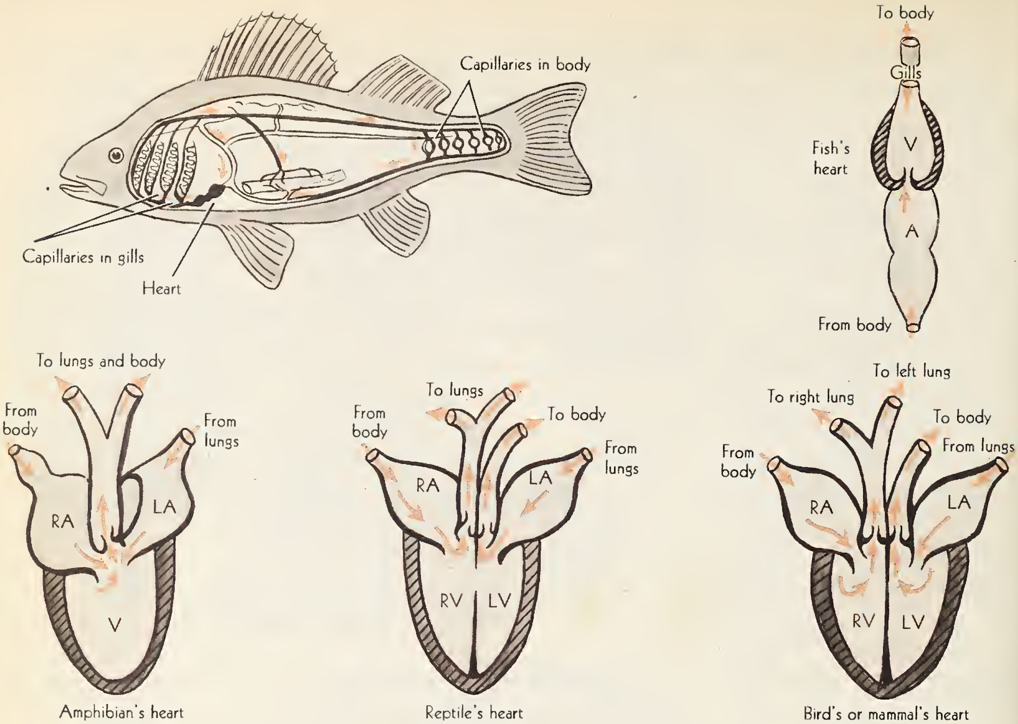
An auricle is a chamber of a heart into which the blood flows from the veins after its journey through the body. A ventricle is a chamber of a heart out of which the blood is forced through the arteries.

In vertebrates higher than the frog, all the blood flows from the heart to the lungs, and then back to the heart, before being forced through the body.

[2]*Auricle* (ô′rĭ kl). [3]*Ventricle* (vĕn′trĭ kl).
[4]Singular, *sinus* (sī′nŭs); plural, *sinuses* (sī′nŭs ĕz).

Circulatory system of an insect and an earthworm. That of an insect is an open vascular system. It is so called because the blood circulates partly through tubes (blood vessels) and partly through irregular spaces (sinuses[4]). The earthworm has a closed vascular system. A closed vascular system is one in which a system of blood vessels carries the blood to all parts of the body. [P]All chordates have closed vascular systems. To which of the principles on page 271 is this principle most closely related?





Partial diagram of the circulatory system of a fish and diagrams of the hearts of the five classes of vertebrates. *R* stands for right; *L*, for left; *A*, for auricle; and *V*, for ventricle. What evidence is presented here which supports the principle The higher an animal is in the scale of life, the more complex are its structures?

MOVEMENT OF CELL CONTENTS · Not only is there a movement of sap or blood throughout the bodies of complex plants and animals, but there is also a movement of the protoplasm within all individual cells. With a compound microscope you can observe a rapid streaming of the cytoplasm in some plant cells—for example, in those of a young leaf of *Elodea*. Less conspicuous movements of the contents of a cell are caused by diffusion and also by changes in the cell's shape due to the movements of the whole organism or of a branch, a leg, or other part of it. All these movements result in distributing the necessary materials throughout the protoplasm and in removing waste substances from it.

CIRCULATION AND BODY TEMPERATURE Circulation in the warm-blooded animals performs still another function, besides supplying all the living cells with necessary substances and carrying away their wastes. It distributes, throughout the body, the heat resulting from the burning of the food in the

cells and from the friction caused by the muscle movements.

DIFFERENCES IN THE VASCULAR SYSTEMS OF PLANTS AND ANIMALS · [E]The preceding discussions reveal that the vascular systems of higher plants differ from those of the higher animals in these important respects: (1) No plant has an organ corresponding to a heart, which forces sap through its phloem and xylem tubes. (2) The vascular system of a plant is not continuous, as is that of a higher animal. There are no smaller tubes connecting the phloem and xylem, such as the capillaries that connect the veins and arteries of an animal. Hence sap does not actually circulate through a plant in the same sense as blood does through an animal's body.

4. How Are the Needs of Human Body Cells Supplied?

People often describe something as having "the color of blood." They mean, of course, the crimson color that is usually associated with blood. But not all blood looks red like ours or like that of other vertebrates or even of some invertebrates. The blood of some insects and of many simpler invertebrates is colorless. That of certain other insects is faintly green or faintly yellow. The blood of such crustaceans as crayfish and crabs is colorless until exposed to the oxygen in the air. Then it becomes blue.

HUMAN BLOOD · You can find out some facts about human blood by studying a drop of your own. Rub the skin on the end of your finger with a bit of absorbent cotton dipped in grain alcohol. Similarly rub a sharp needle with the cotton. The alcohol serves as a germicide to kill the germs on your finger and on the needle. Stick the needle into the end of your finger and squeeze out a drop of blood on a microscope slide. With a cover glass spread the blood on the slide in a thin smear and immediately put the cover glass over it. Rub the cotton containing the alcohol over the "wound" in the end of your finger to kill any germs that might cause an infection.

When now you examine the blood under a microscope, you will see that it is not red, but brown. You will see in the yellow-brown smear of the watery part, or plasma,*[1] many yellowish, disk-shaped bodies. These are red corpuscles.**[2] You will observe also a few larger, irregularly shaped bodies which resemble amebas. These are the white corpuscles, but they are really colorless rather than white (illustration, p. 250).

You cannot learn much more about the blood from such an observation, but the following pages will describe it and how it passes to and from all the living cells of your body.

The parts of the blood. 1. *The plasma.* An average adult person has about twelve pints of blood. From a half to three fifths of it is plasma. The rest is corpuscles and platelets.[3] The plasma passes through the walls of the blood capillaries and becomes the cell fluid, or lymph.[4] The lymph fills the spaces between the cells and bathes the surfaces of all of them. It contains billions of white corpuscles, but never a single red one,

[1]*Plasma* (plăz′mȧ).
[2]*Corpuscle* (kôr′pŭs'l). [3]*Platelet* (plāt′lĕt).
[4]Some physiologists consider the cell fluid to be lymph only after it has entered the lymph vessels

except where the walls of the blood vessels have been cut or broken.

If a large enough tank could be filled with lymph, tropical sea animals would be able to keep alive in it, at least for some time. The reason why they could is that lymph has nearly enough the same chemical composition as sea water. Hence the living cells of your body, surrounded, as they are, by lymph, might be compared to colonies of protozoans living in the warm water of a tropical ocean.

The plasma contains blood proteins of several kinds, which have great medical value. They include the following: (1) a substance which, when injected into the blood, serves as a protection against measles and some other diseases; (2) a plastic useful in surgery; (3) a substance of great value in skin-grafting for the treatment of serious burns; (4) a substance that aids in stopping excessive bleeding (hemorrhage[1]) from wounds; and (5) a substance that prevents shock from wounds or other injuries.

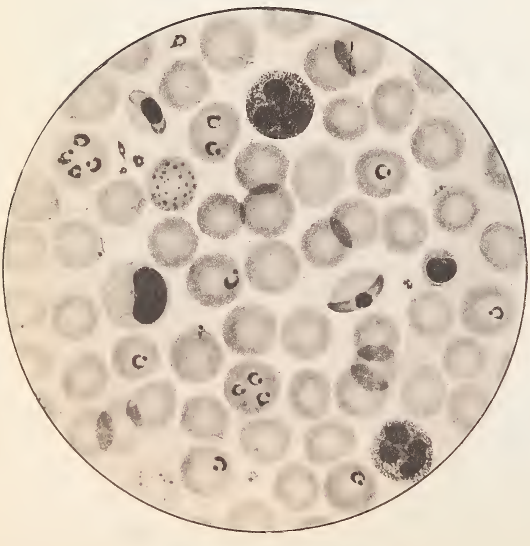
2. *The red corpuscles.* The red corpuscles are formed in the red marrow of the bones. If you were to examine under a microscope some of your red corpuscles and some of a frog's, you would find that yours contain no nuclei, but that the frog's do. When a human red corpuscle is first formed, it has a nucleus. By the time it is mature, however, and enters the blood stream, its nucleus has disappeared (illustration below).

The chief function of red corpuscles is to carry oxygen. This they are able to do because of a red-brown compound of iron, hemoglobin,*[2] that they contain. This com-

[1]*Hemorrhage* (hĕm'ŏ rĭj).
[2]*Hemoglobin* (hē mō glō'bĭn).

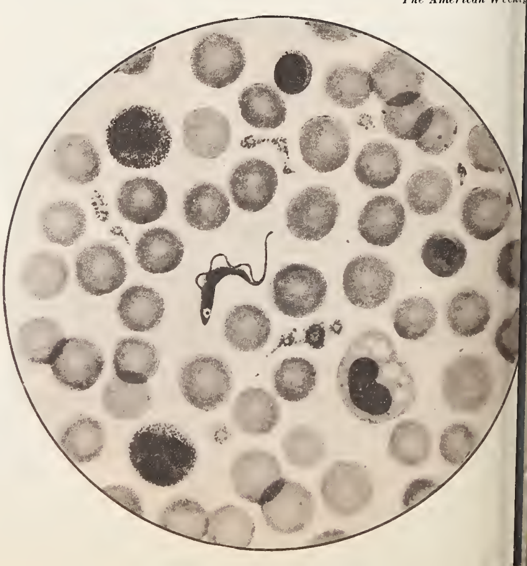
Blood cells · From a study of the text, can you identify the red corpuscles, the white corpuscles, and the blood platelets? Note the malarial parasites in the red cells of *A*, and the protozoan germ of sleeping sickness in the middle of *B*

A



B

The American Weekly



West Michigan Tourist and Resort Association

Why does your blood need to carry more oxygen and carbon dioxide when you are exercising than when you are not? What advantages are there in exercising in the open air?

pound combines to a small extent with carbon dioxide also, but most of the carbon dioxide is dissolved in the plasma. Of course some of the oxygen dissolves in the plasma, too, but the red corpuscles carry more than sixty times as much as the plasma alone could carry.

The blood increases its load of either oxygen or carbon dioxide whenever it passes through a part of the body where that gas is highly concentrated. Also, it gives up either oxygen or carbon dioxide whenever it passes through a part of the body where the concentration of that gas is low. Hence the blood takes on oxygen and gives off carbon dioxide in the capillaries of the lungs. Similarly, it gives off oxygen needed for the combustion of food in the cells and takes on carbon dioxide resulting from such combustion, in all parts of the body.

3. *The white corpuscles.* Normally, the human blood contains about a thousand times as many red corpuscles as white. Like the red corpuscles, some of the white ones are formed in the red marrow of the bones. Others are formed in the lymph nodes (which will be described later) and some probably in the liver.

White corpuscles are of several kinds. All differ from the red corpuscles in the following ways: (1) they do not contain the iron compound (hemoglobin), (2) each has a nucleus, and (3) they are somewhat larger (illustration, p. 250).

One type (leucocytes[1]) moves about and consumes invading germs and injured body cells, by engulfing them in much the same way that an ameba feeds. About three fourths of the white corpuscles are of this type. Another type (lymphocytes[2]) is about a third as numerous as the one just described. This type is believed not to engulf bacteria, but to aid in the healing of injured tissues. The remaining three or more types together make up only about 8 per cent of the white corpuscles. Their functions are not yet known.

[1] *Leucocyte* (lū′kō sīt).

Making a blood donation · Reserve supplies of whole blood or of blood plasma make up a blood bank. **Community Application of Biology:** Find out from your local office of the American Red Cross or from your local hospital what are the plans for establishing and maintaining a permanent blood bank

Johnson, from Red Cross

4. *The blood platelets.* The blood platelets are colorless, roughly disk-shaped bodies about one third as large and one tenth as numerous as the red corpuscles. You will not be able to see them on a microscope slide of your blood. They break up almost at once when they come in contact with unusual surroundings, such as injured tissues or the glass of the microscope slide. They function in causing the blood to clot in a wound. Little more is yet known about them.

BLOOD TRANSFUSIONS · Denis,[3] a French physician, is credited with having performed the first successful blood transfusion on man, over two hundred years ago. He transferred the blood of a lamb directly to the vein of a boy who had been made weak from blood-letting. Blood-letting, or bleeding[4] (taking blood from a sick person), was in earlier times a common treatment for almost any kind of illness.

Strangely enough, this first transfusion was reported to have been successful. Physicians discovered later, however, that whenever a transfusion was made from an animal to a person, the patient almost always soon died. They found, also, that even when the blood transfer was made from one person to another, the patient often died.

It was later discovered that death in such cases is due to chemical changes in the blood

[2] *Lymphocyte* (lĭm′fō sīt).
[3] *Denis* (dē nē′). Lived, ?–1704.
[4] No. 6, p. 271.

of the person receiving the transfusion. It was discovered, further, that these changes are caused by differences between the chemical composition of the animal's blood and that of the person, and even between the chemical composition of the blood of the person giving blood and that of the person receiving it.

Blood types.[1] There are now known to be four types of blood, which must be taken into account in making a transfusion of whole blood. These are types O, A, B, and AB. Blood of type O can be transferred to any person without danger to him. Moreover, a person having blood of type AB can be given blood of any type. In all other cases the type of blood given in a transfusion must be the same type as that of the receiver.

[E]These four types of blood are distinct because of differences in their chemical compositions. These differences are not racial. They are individual. Thus the Japanese as a people do not have a type of blood that is different from that of any white people. Individual Japanese and individual white people have the same types of blood. Therefore, whenever a transfusion of whole blood is given, the donor (the person who gives his blood) may be a person of any race, so long as his blood is of the right type.

Blood plasma in transfusions. During the Second World War the impossibility of supplying enough whole blood, fresh enough to be used in distant battle areas, led to the invention of a method of preparing and using dried blood plasma for transfusions. The American Red Cross established centers where any healthy person who wished to do so could donate a pint of his blood (illustration, p. 252). Patriotic citizens of every racial stock answered the appeal for blood to save the lives of wounded men. Millions of pints were thus obtained. A few donors, over a period of many months, gave as many as eighteen or more pints of their blood

The blood plasma was separated from the corpuscles and dried. A straw-colored powder remained. The dried plasma from all sources could be combined because there are no types of blood plasma. Hence any of the powdered plasma could be made ready to be transferred to anybody's veins by being dissolved in distilled water.

Blood proteins in transfusions. Later it was found that one of the blood proteins (serum albumin[2]) could be used in many cases as effectively as whole plasma. This protein could be readily separated from the rest of the plasma and, in dried form, took up only one sixth as much shipping space. It had the advantage, not possessed by whole plasma, of preventing the shock which commonly results from wounds and burns. For cases of excessive bleeding, however, transfusions of neither plasma nor blood protein would serve. Whole blood, containing the red corpuscles, was needed.

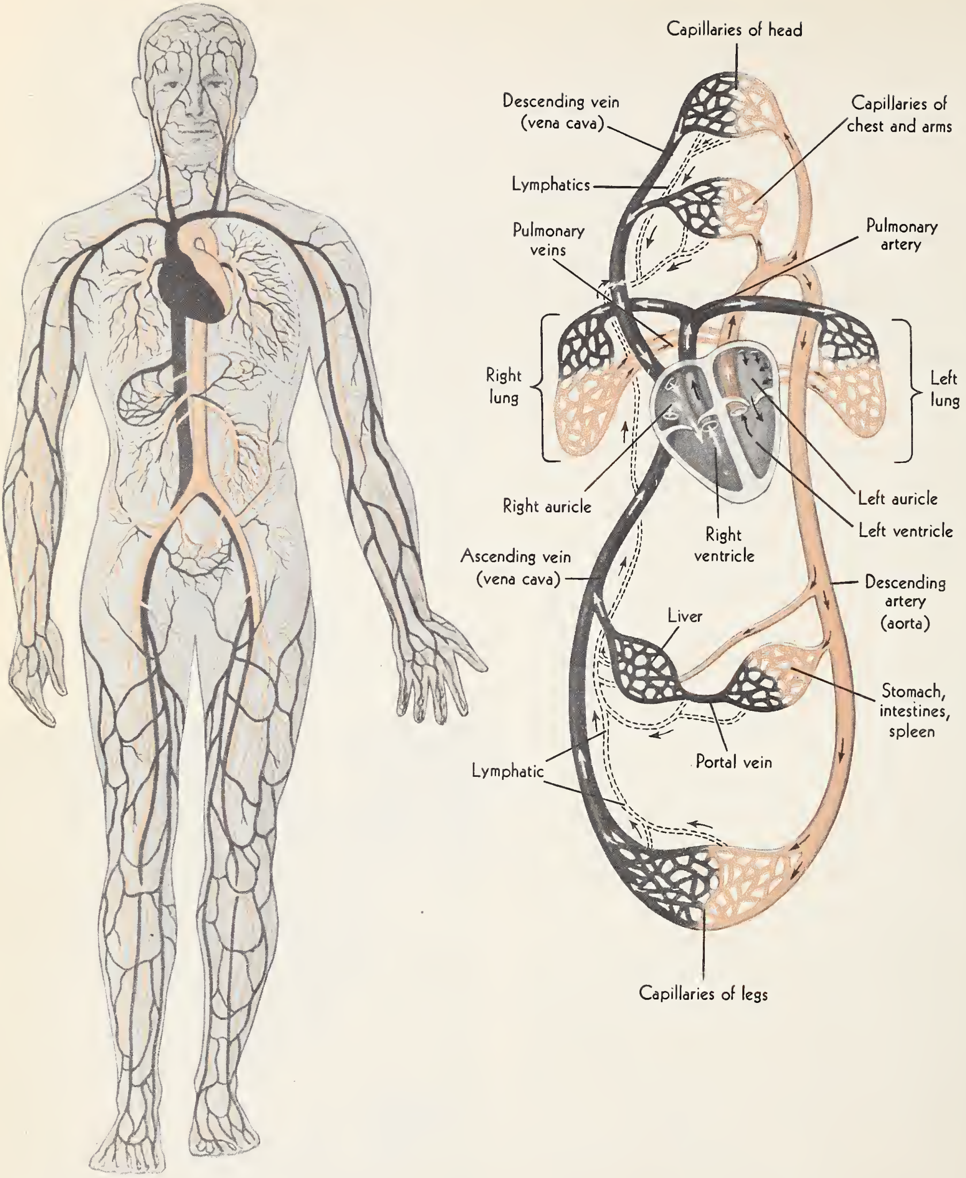
In 1944 a means of refrigerating and preserving was invented, by which whole blood could be used after as long a period as three weeks from the time that it had been taken from the donor.

Some uses have already been found for the red blood corpuscles which remain when plasma for transfusions is separated from whole blood. When used as a powder or as a paste, the red corpuscles hasten the healing of certain types of wounds and ulcers. Also, some people suffering from anemia,[3] a disease that results when the blood fails to supply

[1]Although *blood group* is a more accurate term than *blood type*, and is the term commonly used by scientists, the more familiar term *type* is used in this discussion.

[2]*Serum albumin* (sēr′ŭm ăl bū′mĭn).

[3]*Anemia* (ȧ nē′mĭ ȧ).



Circulation in man · The circulation through the arteries is indicated by orange, and that through the veins by black. The circulation of the lymph is indicated by dotted lines. Can you trace the circulation from any point in a blood vessel and back to the same point?

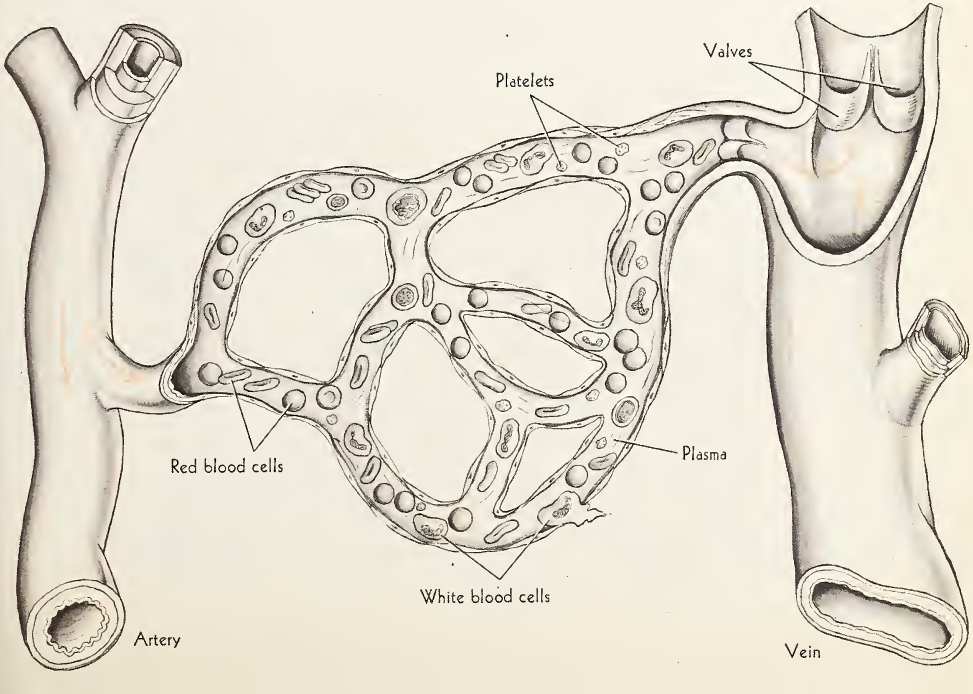
enough oxygen to the body, have been helped by having red corpuscles of the right type put into their blood.

After the Second World War the American Red Cross distributed the surplus blood plasma, free of charge, to hospitals in many countries, to be given to all who needed it. Also, the Red Cross encouraged people to continue to donate their blood in order to maintain existing blood banks and to establish others.

BLOOD CIRCULATION AND RELATED PROCESSES · Describing the processes of blood and lymph circulation and of respiration is like telling a story in which different events are happening all at the same time, but at different places. These processes, which must be described separately, are going on constantly. Moreover, they are not entirely separate processes, but are really closely related parts of the great and complex process of nutrition.

THE CIRCULATORY SYSTEM · If you were to put a handful of absorbent cotton, well moistened with ether, into a jar containing a frog, and were to cover the jar, the frog

The flow of blood from an artery, through capillaries, and into a vein.
A capillary wall continues into a vein or an artery as its inner lining. A vein has two other layers of tissue: a middle one, composed of muscle tissue and elastic fibers, and an outer layer of supporting tissue and elastic fibers. An artery is much like a vein in structure except that its middle layer is much thicker. Can you explain why blood spurts in jets from a cut artery, but flows steadily from a cut vein?

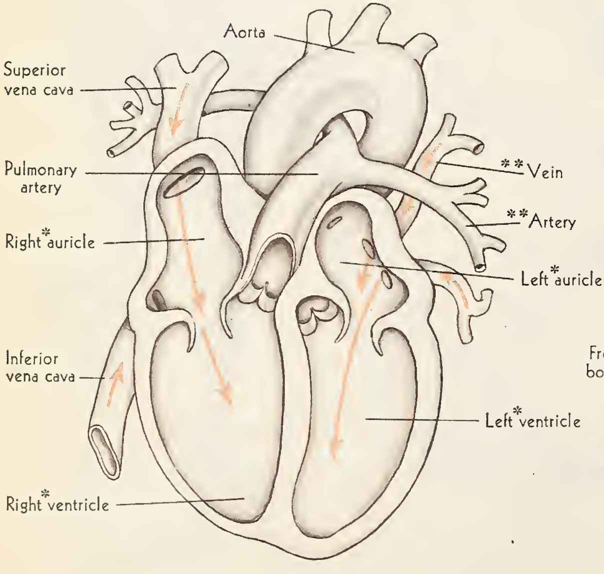


would become anesthetized[1] in about fifteen minutes. If, instead, you were to wrap a goldfish in cotton first made fairly wet with water and then further moistened with ether, the animal would become quiet almost at once. With a compound microscope you could then observe the flow of blood through the capillary tubes in the web of the frog's foot or in the tail or a fin of the fish. You would note that the smallest capillaries are just large enough for the red corpuscles to float through them in single file (illustration, p. 255).

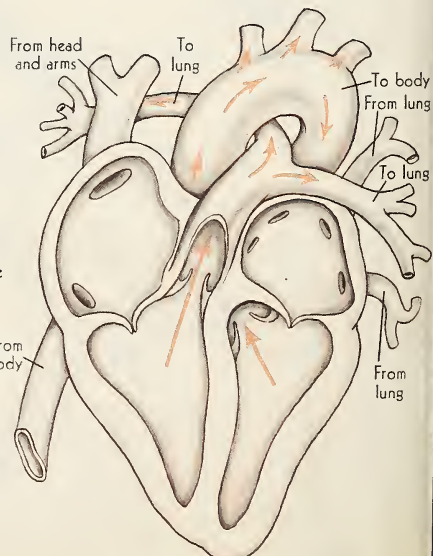
Imagine now that you are similarly observing the capillaries in the end of your finger. If you could see them, they would look like the frog's or the fish's capillaries. You would see the red corpuscles floating through them in the same way. The smallest human capillaries are about one fiftieth as big around as the smallest human hair. It would take more than three thousand of them side by side in a line to measure an inch. Yet they are so numerous that if all of them

[1]An animal that is *anesthetized* (ăn ĕs′thē tīzd) is one that has been made partly or wholly unable to feel pain or other sensation. The substance, such as ether, that is used to produce this condition is called an *anesthetic* (ăn ĕs thĕt′ĭk).

***A*, the heart muscles relaxed; *B*, the heart muscles contracted and hence causing a beat.** From the text and these diagrams can you explain the action of the valves and the movement of the blood in each diagram? The human heart beats about one hundred thousand times each day and rests for about one sixteenth of a second between beats. In less than twenty-four hours it does an amount of work equivalent to that which would be done in lifting a person of average size from the street to the top of the Empire State Building in New York City, one hundred and two stories high



A. Heart with muscles relaxed



B. Heart with muscles contracted

Blair Academy

Can you explain why it is necessary for a person's heart to beat faster when he is exercising violently than when he is quiet?

could be put end to end, they would extend about a hundred thousand miles.

If you could observe the blood as it flows from the capillaries in your finger to your heart and back, and could study the different structures along the way, this is what you would discover:

From capillaries to the heart. The blood passes through small capillaries into larger ones, and these lead into a vein (illustration, p. 255). The walls of a capillary are made up of flat, thin cells, which readily permit osmosis through them. Also, there are minute spaces between the cells of the capillary walls, through which plasma diffuses and white corpuscles crawl out into the spaces surrounding the body cells.

The smallest veins lead into larger ones, and these are joined by other veins. Together they form a system that is much like a river system in which the smaller streams flow into larger ones and these finally into the main river. Finally one large vein (inferior vena cava[1]) flows into the right auricle of the heart. Another (superior vena cava), containing blood from the upper parts of the body, likewise flows into the right auricle (illustration, p. 256). The blood from the veins contains much dissolved, digested food. Also, it contains much carbon dioxide and relatively little oxygen. It looks bluish-red.

Here and there in the veins, especially in those that flow upward, are seen bag-like valves. These valves permit the blood to

[1]*Vena cava* (vē'nȧ kā'vȧ).

flow toward the heart, but prevent it from reversing its direction.

Through the heart. The heart is a double pump inside a double-walled bag (pericardium[1]). It may be thought of as resembling two fish's hearts (illustration, p. 248), attached to each other and both beating at the same time (legend, illustration, p. 256). One side pumps blood through the lungs. The other side pumps blood through the rest of the body. Each pump consists of two chambers, and between the two chambers is a valve, similar to the valves in the veins, only larger. The valves in the heart act like those in the veins in that they prevent the blood from flowing back in the direction from which it came.

The blood from the two great veins flows into the right auricle while the heart muscles are relaxed, between beats (illustration *A*, p. 256). Then the muscles of the right auricle contract, and thus force the blood into the ventricle. Next, the muscles of the right ventricle contract (illustration *B*, p. 256), forcing the blood out of the ventricle into the pulmonary*[2] artery.

From the heart through the lungs. The pulmonary artery divides, one branch leading to each lung. Each branch divides into smaller and smaller arteries, which finally lead to the network of capillaries in the lung tissues.

The flow of blood in the arteries may be compared to that of a river flowing backward. In other words, the current flows from the main branch into smaller and smaller branches. Thus the blood flows, through the system of arteries, in the opposite way to that in which it flows through the system of veins.

The surge of blood through all the arteries, at every heart-beat, is the pulse. The force of this wave is constantly being opposed and reduced by the elastic tissues of the artery walls. As a result, by the time the blood passes from the smallest arteries (arterioles[3]) into the capillaries, it is flowing steadily. Also, it is flowing slowly.

When the blood reaches the lung capillaries, carbon dioxide passes out of it through the capillary walls into the minute air spaces in the lungs. At the same time oxygen passes into it from these same spaces. The blood now contains much oxygen and relatively little carbon dioxide. It no longer looks bluish, but is scarlet.

How the lungs are constructed and how they function will be described later.

From the lungs back to the heart. The capillaries of the lungs lead into veins, as did those in the finger.[4] Finally two great veins carry the blood from each lung into the left auricle of the heart. Here the heart action already described is repeated (illustration, p. 256). The contraction of first the auricle and then the ventricle forces the blood into the great artery, called the aorta.*[5]

From the heart back to the capillaries. As the blood containing oxygen and food flows to all parts of the body, it passes through numerous smaller and smaller arteries and finally into the capillaries, as it did in going from the lungs to the heart. One of the arteries leads into the network of capillaries in the finger. There the round trip is completed.

The whole cycle, from finger to heart, to lungs, to heart, and back to finger, has taken only a fraction of a minute. In fact, the blood makes its longest complete circuit, that from the heart to a toe and back, more than twice in one minute. Remember that the blood is moving throughout the entire circuit of blood

[1]*Pericardium* (pĕr ĭ kär′dĭ ŭm).

[2]*Pulmonary* (pŭl′mō nĕr ĭ): having to do with the lungs.

[3]*Arteriole* (är tēr′ĭ ōl).

[4]Page 256.

[5]*Aorta* (ā ôr′tȧ).

The liver is the largest gland in the body. This diagram indicates some of the activities carried on within a minute liver vessel. How many of the numbered bodies can you identify? How many functions of the liver can you state? Make your list first. Then consult the Index to find additional functions

vessels at the same time, just as the riders on a merry-go-round or a carnival Ferris wheel are all in motion at once.

FUNCTIONS OF THE LIVER · The liver takes some sugar from the blood and stores it in the form of animal starch, or glycogen,*[1] in its tissues. This serves as a reserve supply of energy which is poured into the blood whenever needed as fuel for the cells, and especially when much extra fuel is needed for an unusual effort (illustration, p. 257).

If the blood has absorbed nicotine from smoking, caffein from drinking coffee, tea, and certain soft drinks, or certain other poisons, including morphine, the liver changes these poisons into harmless substances. Also, certain cells of the liver engulf and digest bacteria and worn-out red corpuscles, in much the same way that certain cells in the body walls of sponges[2] and hydras[3] engulf food particles (illustration above).

CIRCULATION AND TOBACCO · It has been discovered that nicotine causes the walls of blood vessels to contract slightly. Under normal conditions this contraction is of little or no consequence. Smoking by a person who has just suffered a severe wound, however, from accident or other cause, may, in rare cases, be followed by serious and permanent effects (illustration, p. 260).

CIRCULATION AND ALCOHOL · Drinking alcoholic liquor causes the pulse to beat faster and the blood vessels in the skin to dilate (enlarge). As a result, the person feels warmer, but is actually losing heat and is getting colder.

[1]*Glycogen* (glī′kō jĕn).

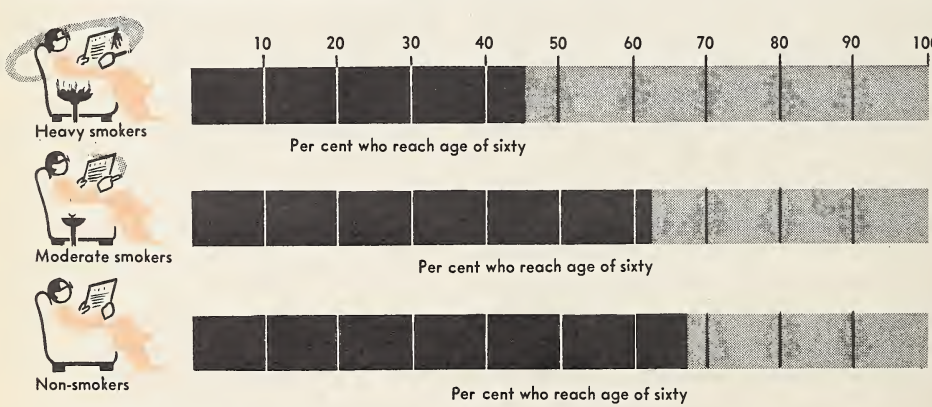
[2]Page 515.

[3]Page 230.

THE LYMPHATIC SYSTEM · As has been stated, the blood plasma is constantly diffusing out between the cells of the capillary walls. It supplies the cells with food, oxygen, and other materials that they need and receives waste products from them. Relatively little of it goes back into the blood stream through the capillary walls. Most of it flows, as lymph, into lymphatics,*[1] or lymph vessels. These open from the cell spaces in all parts of the body. The smaller ones lead into larger ones, just as capillaries lead into veins. The lymph from the cell spaces is joined by that which contains the digested fats and which flows from the lymph vessels inside the villi.[2] The lymph is poured from the largest lymph tubes into veins in the neck, and again becomes plasma (illustration, p. 261).

COMPARISON OF THE CIRCULATORY AND LYMPHATIC SYSTEMS · The human lymphatic system differs from the human circulatory system in several ways: (1) It is not a continuous system, and consequently is not truly a circulatory system. It may be compared to the part of the circulatory system that includes the capillaries and the veins, but not the arteries. (2) It has no heart, though some of the lower vertebrates do have simple lymphatic hearts. In mammals the lymph is forced along by the breathing movements and other muscular actions. (3) The lymph moves through the lymph vessels much more slowly than the blood flows through the veins. It is kept flowing always in the same direction by valves in the lymphatics, similar to those in the veins. (4) At numerous points in the lymph vessels are spongy structures, called lymph nodes or lymph glands (illustration, p. 261). The tonsils are examples of such glands. As the lymph slowly flows through the lymph nodes, they strain out of it and retain solid impurities, such as particles

[1] *Lymphatic* (lĭm făt'ĭk). [2] Page 238.



This illustration shows the results of a recent study. The top line is read thus: Forty-six out of every hundred heavy smokers who are thirty years old may be expected to reach the age of sixty. Can you interpret the other two lines? What inference do you draw from these results? The facts about the effects of alcohol upon length of life show that in general heavy drinkers have a higher death rate at every age than moderate drinkers or non-drinkers

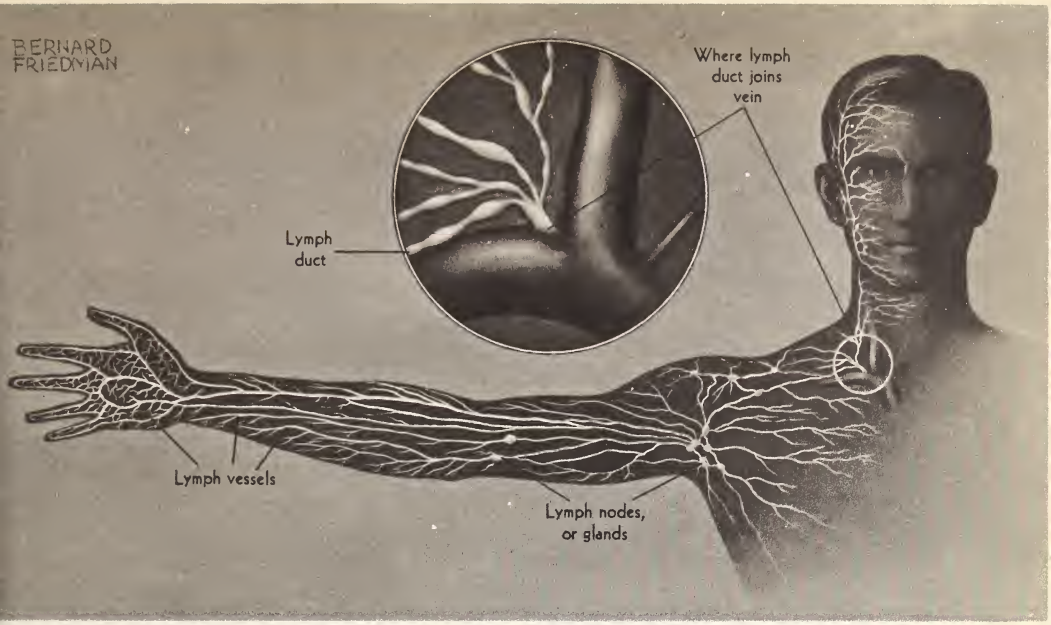


Diagram of part of the lymphatic system · What causes the flow of lymph from the cell spaces into the lymphatics? Should you expect the walls of the smallest lymphatics to be similar to the walls of the capillaries? Explain

of dirt that get into the body through cuts, and particles of soot and dust that get into the blood from the lungs. The lymph nodes always contain enormous numbers of white corpuscles. These prey upon bacteria and other germs that may be in the lymph. Thus they perform an important function in protecting the body against diseases.

ASSIMILATION · Perhaps you have heard the old saying "Everyone has a completely new body every seven years." The saying is, of course, untrue, but, like some other untrue sayings, it has a grain of truth in it. It indicates that the body is constantly changing, as worn-out structures are replaced with new ones.

As has been stated, the sap of a plant or the blood of an animal brings digested foods and all other necessary substances to every living cell in the organism. These substances pass by osmosis[1] into the cells. There assimilation takes place. Assimilation consists of the chemical changes by which the protoplasm synthesizes, or builds up, new protoplasm out of these various materials. Exactly how assimilation is brought about is not yet known. Scientists have never yet been able to discover how living material (protoplasm) can make more living material out of non-living materials.

THE BREATHING STRUCTURES · If you were to examine the breathing system of a dissected frog, you would find a pair of hollow bags at the ends of two branches of a tube leading to the throat. These bags are the lungs. If you

[1]Footnote, p. 151.

were to dissect one of them, you would discover that its inner surface has numerous folds and wrinkles. These greatly increase the area that is exposed to the air as the frog breathes.

The breathing system of a mammal (for example, man) is much like that of the frog, though more complex. It has two elastic, bag-like lungs, each inside another bag of tissue (pleura[1]) (illustration, p. 263). A complex system of air tubes runs through all parts of each lung. The smallest tube could barely be seen with the naked eye. Each has walls made up of flat, thin cells, similar to those that make up capillary walls. These tubes lead into larger and larger ones, much as capillaries lead into small veins and these into larger veins. Finally two large tubes (bronchi[2]), one from each lung, join to form the windpipe, or trachea. This leads to the throat and through it to the air passages through the nose.

Each of the smallest air tubes ends in a cluster of microscopic sacs, or bag-like structures (alveoli[3]). These enclose minute air spaces, which number millions. A network of blood capillaries runs through the walls of these sacs. It is estimated that the total surface areas of the sacs and the capillaries equal the area of a small city lot.

When air is inhaled (breathed in), oxygen passes through the moist walls of the air sacs and of the capillaries into the blood. At the same time carbon dioxide passes from the blood through these walls into the air sacs. When air is exhaled (breathed out), much carbon dioxide, received from the blood, is forced out of the body. So also is considerable water vapor, which has evaporated from the moist walls of the tiny air sacs into the spaces inside them.

MOUTH BREATHING · When a person has a severe head cold, he is likely to breathe through his mouth. Normally, however, he should breathe through his nose. Mouth breathing commonly results from one of two causes: (1) Certain passages of the nose become closed, more or less completely, by growths (adenoids[4]). This condition develops more often in children than in adults. (2) Tissues and bones of the nose grow abnormally and thus prevent the free passage of air through the nose. Such a development is often the result of an old injury. For example, sometimes a young child breaks its nose in a fall without the parents' discovering that it has done so. Injuries to the nose structures that do not heal properly are not uncommon among older children and adults. Years later, breathing difficulties may develop from such injuries.

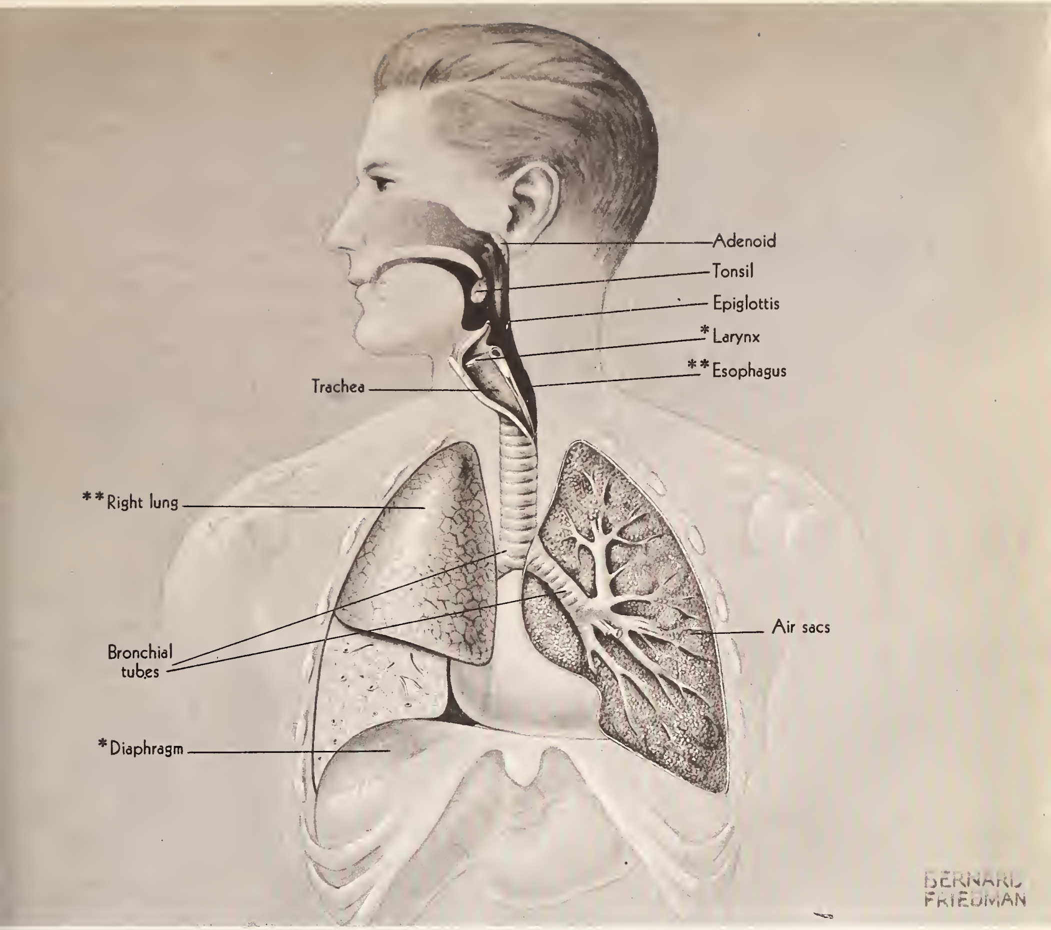
In all cases of abnormal breathing habits, a specialist in diseases of the nose should be consulted.

RESPIRATION AND FLYING · If you have ever climbed a mountain, you know that you had to breathe rapidly and that you tired easily. Also, you may have had altitude sickness. These and other effects are due to the diminishing supplies of oxygen in the air as the altitude increases.

About seventy-five years ago three scientists made a balloon ascension to study the effects upon the human body of the conditions existing at high altitudes. They rose to a height of more than five miles in the open basket of the balloon. At a height of about twenty-four thousand feet, one, Crocé-

[1] *Pleura* (plōōr′ *ȧ*).
[2] *Bronchi* (brŏng′kī); singular, *bronchus* (brŏng′kŭs).
[3] *Alveoli* (ăl vē′ō lī); singular, *alveolus* (ăl vē′ō lŭs).

[4] *Adenoid* (ăd′ē noid).



The human breathing structures · Consumer Biology: From time to time, the people who set the fashions for women's clothing try to make popular again the "wasp-waisted effect," which brought injury to the health of many women about half a century ago. How would such a fashion affect respiration and other physiological processes? Ask a physician

Spinelli,[1] was gasping for breath. The second, Sivel,[2] was almost unconscious. Only the third, Tissandier,[3] still had sufficient command of his mind and body so that he was able to cut loose three sandbags and thus cause the balloon to rise still higher. He was then overcome by a fit of laughing, as if he had become drunk. He tried to shout to the other two, but could not make a sound. All three became unconscious. Crocé-Spinelli and Sivel died while still in the air. Tissandier became conscious again as

[1]*Crocé-Spinelli* (krō sā′ spē nĕl′lē). [2]*Sivel* (sē vĕl′).
[3]*Tissandier* (tē sän dyā′).

the balloon was descending, and later recovered.

There were containers filled with oxygen in the basket of the balloon, and the oxygen would have saved all three men had they breathed it. But they were suffering too much from the lack of oxygen to be able to use the containers.

The lack of sufficient oxygen brings on in fliers a dangerous condition (anoxia[1]) similar to that which Tissandier experienced. In the first stages the aviator feels gay and unusually well. But soon, he is unable to see or hear clearly. Planes now, however, are commonly equipped with "pressurized cabins." Within these the air pressure is automatically prevented from becoming less than that which

[1]*Anoxia* (ăn ŏk'sĭ *ȧ*).

Why do you breathe more rapidly when you exercise strenuously? **Topic for Individual Study:** Consult a college textbook of physiology to find out exactly why and how the air is forced into your lungs when you inhale, and why and how it is forced out when you exhale. Prepare a report to be made before your classmates or in your science club

Sanders, from Black Sta

exists at an altitude of about ten thousand feet. In planes thus equipped, flying without discomfort is possible at heights of eight or more miles above sea level (illustration, right).

CARBON MONOXIDE "POISONING." No doubt you know of instances in which people were killed by breathing carbon monoxide from the exhaust fumes of automobile engines running in closed garages, from leaking gas stoves or gas fixtures, or from the fumes escaping from furnaces or smoke-pipes.

Carbon monoxide combines with the red corpuscles of the blood more readily than oxygen does.[1] Moreover, a red corpuscle that is carrying carbon monoxide cannot carry any oxygen. Therefore anybody who breathes air containing as much as two to four parts of carbon monoxide in a hundred parts of air dies in ten minutes or less. He does not, however, die from poisoning. He dies or, as it were, drowns from a lack of enough oxygen, just as he drowns if he is submerged too long in water.

ARTIFICIAL RESPIRATION · Everybody should know how to apply artificial respiration to victims of drowning, gas poisoning, or electric shock. Start artificial respiration *at once* and continue until a physician pronounces it no longer necessary. Place the subject on a slight slope so that any water that may be in his respiratory organs will drain out. Thrust your finger into his mouth and press his tongue forward to make sure that it is not closing the air passage. Do this again from time to time between cycles. Place the subject's hands one upon the other and rest the *upper part* of his cheek upon the top one. Turn his head only slightly. Close his mouth. His mouth should be within about an inch of the ground. Keep his neck straight (extended) during all the time that artificial respiration is being applied.

Press Association

In diving, the pilot sometimes suffers a "black-out," lasting from one to twenty seconds, when the plane is pulled out of the dive or occasionally when it makes a sharp turn. The cause is that the heart is unable to force a normal amount of blood to the head. **Topic for Individual Study:** The relation of inertia and acceleration to "black-outs." (Look up *inertia* and *acceleration* in a textbook of physics)

(*A*, illustration, p. 266.) Kneel on one or both knees. Place both hands, with fingers spread and thumbs touching, so that the heels of the hands lie just below a line running from one of the subject's armpits to the other. (*B*) Slowly rock forward. Do not press hard. Merely let the weight of your body exert a steady and even pressure upon the subject's back. Do not give a final shove. (*C*) Lift your hands and grasp the subject's

[1]Page 251.

Getting ready to begin the cycle

Forcing air out of the lungs

Releasing the pressure and shifting the hands

Expanding the lungs so that air will enter them

arms just above the elbows. (*D*) Slowly rock backward, drawing the subject's arms both toward you and *upward*, enough so as to lift his chest partly or completely off the ground. (*A*) Release his arms, take the first position again, and continue the cycle.

Complete twelve cycles per minute. Maintain a slow, steady rhythm. Phases *B* and *D* should occupy equal time. The changes from position *D* to *A* and from *C* to *D* will together require less than a second.

While artificial respiration is carried on, the subject should be covered with a blanket as completely as possible, to prevent his chilling. If he is a victim of drowning, hot-water bottles, not hot enough to burn him, should be placed against him.

Even after the subject has begun to breathe, keep him in position *A* until a physician pronounces him able to rise or until he does so of his own accord.

RESPIRATION AND TOBACCO · The extent to which smoking is harmful to the respiratory organs is not completely known. It irritates the throat and passages of the nose, sometimes keeping them inflamed and causing persistent coughing. Scientists agree that all the effects that smoking may have upon the respiratory structures are harmful.

5. How Do Living Things Get Rid of Wastes?

Have you ever had any experience with wood-burning or coal-burning stoves? Until fairly recent times most cooking and home-heating was done with them. Such a stove is provided with a chimney so that the carbon dioxide, water vapor, and other products of combustion can immediately be removed from where the combustion is taking place. Whenever the chimney fails to "draw,"—that is, whenever the waste products do not go up the chimney immediately, but remain in the stove,—the fire promptly "goes out."

Similarly, in an automobile or airplane engine the water vapor, carbon dioxide, and other gases resulting from the combustion of the gasoline must be forced out of the cylinder where the combustion has occurred and into the exhaust pipe. It is necessary for them then to be forced from the end of the exhaust pipe, out of the automobile entirely.

THE NEED FOR WASTE REMOVAL · EP No plant or animal can live long if it remains surrounded by all its own waste products. This principle was discovered centuries ago by biologists who tried to maintain cultures of protozoans or other organisms for study. The waste products resulting from metabolism must be removed, just as must the products of combustion in stoves and gasoline engines

THE PROCESS OF WASTE REMOVAL · EXCRETION · **In plants** · Carbon dioxide and excess water pass out of simple plants by osmosis. These waste products of metabolism are eliminated from higher plants through the stomata, lenticels,[1] and roots (illustration, p. 268). Urea and other nitrogen compounds, though they are products of metabolism in all living cells, are rarely or never eliminated as waste substances from plant cells, as they are from animal cells. They are used by the plant cells to make new protoplasm.

The carbon dioxide excreted from plant roots forms an acid with the soil water. If the soil drainage does not carry off most of this acid, the acid is likely to become concentrated enough to kill the plants.

Minerals dissolved in soil water are constantly diffusing from the soil into plant roots. The plants cannot use all the elements that compose the minerals. Those that they do not use are not waste materials in the same sense as are the waste products from metabolism. Yet they must be eliminated. Otherwise some of them would injure, or perhaps even kill, the plants.

Chemical processes change most of these unused elements into new compounds. They are stored in various forms, such as gums, resins, crystals, and oils, in leaves, bark, fruit skins, seed coats, the pith of stems, and the vascular and other structures of stems and roots. Most of these substances are eliminated from the plants when they shed leaves, bark, fruits, or seeds.

These substances are the sources of some of our important drugs, including morphine,[2] quinine,[3] cocaine,[4] digitalin,[5] and atropin.[6] From others are manufactured perfumes, dyes, flavoring extracts, adhesives, and an increasing variety of other products.

In animals. Waste products from metabolism pass out of the cells of the Protozoa and of the simpler Metazoa by diffusion and osmosis. In the Protozoa waste materials, dissolved in water, collect in bubble-like spaces (contractile vacuoles[7]). From these, at in-

[1]Page 164.

[2]*Morphine* (môr′fēn). [3]*Quinine* (kwī′nīn).
[4]*Digitalin* (dĭj ĭ tā′lĭn). [5]*Cocaine* (kō kān′).
[6]*Atropin* (ăt′rō pēn).
[7]*Contractile vacuole* (kŏn trăk′tĭl văk′ū ōl).

tervals, the wastes burst out through the cell walls of the animals (illustration, p. 391). Sponges[1] have ameboid (ameba-like) cells, much like our white blood corpuscles, which carry to the outside of the body some waste materials from the cells. Hydras[2] squirt out, through the mouth, from time to time, the wastes from the digestive cavity.

Many of the invertebrates have simple excretory systems. These consist of coiled tubes which extend throughout the body. Waste products from all the living cells osmose into them. In some animals, such as the earthworm, these tubes open outside the body. In others, such as the insects, they empty into the digestive system. Another means of excretion possessed by some arthropods is suggested by the illustration on page 270.

Instead of having such tubes running throughout their bodies, the vertebrates and a few of the invertebrates have them all located in one kidney or a pair of kidneys. The circulating blood brings wastes from the cells to the kidneys, just as it brings carbon dioxide to the lungs or the gills. A tube from each kidney carries surplus water, containing dissolved waste compounds, to a bag-like bladder. A tube (urethra[3]) from the bladder conveys the liquid outside the body.

In nearly all the vertebrates, except the mammals, the wastes from both the bladder and the digestive system pass into the same chamber (cloaca[4]). From this organ they pass together through the anus out of the body.

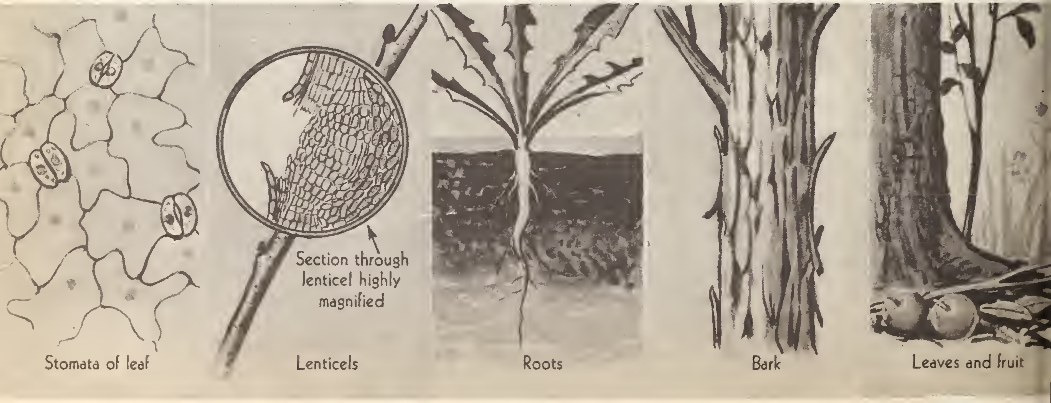
In man. [E]How some waste materials are eliminated from the human body has been explained in preceding sections. Carbon dioxide and water vapor pass from the lungs out through the nose. Bile, made up largely of waste materials resulting from the breaking up of worn-out red corpuscles in the liver, is eliminated, along with undigested foods, from the intestines. Small quantities of salt, urea, and some other waste substances are eliminated, along with surplus water, in sweat from the skin and in urine.**[5] Most of these waste substances, however, are eliminated through the kidneys (illustration, p. 272).

Two complex networks of small tubes run through the tissues of the kidneys. One of these networks consists of small arteries, capillaries, and veins. The other is made up of minute tubes, in which urine collects.

[1]Page 515. [2]Page 230.

[3]*Urethra* (ū rē′thrȧ). [4]*Cloaca* (klō ā′kȧ).
[5]*Urine* (ū′rĭn).

Structures by means of which plants get rid of wastes · Can you name others not shown here?



Ninety-six per cent of urine is surplus water. Four per cent is dissolved urea, other organic wastes, and minerals, chiefly salt.

The urine passes from minute tubes into larger and larger ones, in much the same way that blood flows from small capillaries into larger ones and then into veins. Urine is constantly flowing from each kidney through a tube (ureter[1]) into the bladder.

The bladder serves as a reservoir which makes possible the elimination of the urine at intervals.

Checking What You Know

BIOLOGICAL FACTS · (*Do not write in this book.*) **Pages 227–232.** **1.** The process by which plants and animals change complex foods into simpler substances which all the cells can use is known as --?--.

2. By digestion carbohydrates are changed to --?--, proteins are changed to --?--, and fats are changed to --?-- and --?--.

3. The substances that actually digest the food of every plant or animal are *hormones*, or ferments.

4. Digestion in *green* plants takes place out side their bodies.

5. Name the four main divisions of the digestive system of a vertebrate or a higher invertebrate.

6. The digestive organs of vertebrates in which food is stored until it can be digested are the --?-- and the --?--.

7. The organ in which most of the digestion of a vertebrate takes place is the (1) mouth; (2) crop; (3) stomach; (4) esophagus; (5) large intestine.

8. Two types of glands are the --?-- and the --?-- glands. The digestive fluids are all produced by the *duct* glands.

Pages 232–241. **9.** The salivary glands are *ductless* glands that secrete saliva. Saliva starts the digestion of *starches.*

10. State five functions performed by the hydrochloric acid in the stomach.

11. Food is moved through the digestive system by muscular action called *paralysis.*

12. Enzymes secreted in the stomach begin the digestion of *starches* and *milk.*

13. What are the functions of the bile and the pancreatic juice?

14. The digestion of foods is completed in the *stomach.*

15. What two muscular actions take place in both the small and the large intestine?

16. The digestion that takes place in the large intestine is caused by the action of *enzymes.*

Pages 241–249. **17.** State the five processes that make up metabolism and that go on simultaneously (all at the same time).

18. Substances can pass into or out of cells only if they are in *solid* form or are *dissolved* in liquids.

19. Oxygen passes into one-celled organisms, and waste materials pass out of them, by (1) osmosis; (2) digestion; (3) photosynthesis; (4) peristalsis; (5) a complex muscular action.

20. The respiratory structures of *all* vertebrates and also of the higher invertebrates have great areas of absorbing surface.

21. A class of vertebrates many of which absorb oxygen through both their moist skins and their lung tissues is the (1) fishes; (2) amphibians; (3) reptiles; (4) birds; (5) mammals.

22. There are *no* invertebrates and *few* vertebrates that have open vascular systems.

23. State the chief differences between the vascular systems of plants and those of animals.

[1] *Ureter* (ū rē′tẽr).

United States Bureau of Entomology and Plant Quarantine

Here a young cicada (nymph[1]) is molting (shedding its exoskeleton) and becoming an adult. Molting is believed to be one means by which insects and crustaceans get rid of some waste materials. Do you recall another reason why such animals molt?

Pages 249–266. **24.** Name and describe briefly the chief parts of the blood.

25. The cell fluid, or lymph, is formed from the __?__ in the blood vessels. The *lymph* normally contains billions of red corpuscles.

26. The liquid parts of the blood and the cell fluid bring necessary substances to *all* living cells and carry away their waste substances.

[1]Page 182.

27. Disease germs and injured cells are "eaten up" by certain *blood platelets.*

28. Blood transfusions are made with whole blood, with __?__, and with __?__.

29. Trace the path that the blood follows in going from one of your toes to your heart and back, and from your left ear to your heart and back. What parts of the journey would be the same in both cases?

30. State three functions of the liver.

31. New protoplasm is built by living cells from dissolved substances in the lymph by the process of (1) circulation; (2) osmosis; (3) respiration; (4) digestion; (5) peristalsis.

32. Trace the path followed by air entering your nostrils to a point where it gives up oxygen and takes up carbon dioxide, and thence back to your nostrils.

33. Compare the human circulatory system with the human lymphatic system, stating both the similarities and the differences.

34. *A vein* has two more layers of tissue in its walls than *an artery.*

Pages 267–269. **35.** The important waste products of all living things include *oxygen,* water, and urea.

36. Failure to remove the waste products of metabolism results sooner or later in the __?__ of the organism.

37. Plants dispose of *energy foods* which they cannot use by changing them into different substances and then storing them in various structures.

38. In higher animals the *intestines* are the chief organs for removing cell wastes from the blood.

39. *Some* waste materials are removed from the human body along with *sweat,* undigested materials from the intestines, expelled air from the lungs, and urine from the kidneys.

BIOLOGICAL PRINCIPLES · **1.** Living things change foods, both chemically and physically,

from the forms in which they are found into forms in which they can be used.

2. In higher animals digested foods and oxygen, together with other essential substances, are carried by the blood to all the cells.

3. In the vertebrates and most groups of invertebrates waste materials pass, by osmosis, out of the cells into the blood, which takes them to the kidneys, where they are eliminated.

4. Generally speaking, the higher an organism is in the scale of life, the more complex are its structures. Sometimes this principle is stated thus: Complexity of structure goes hand in hand with division of labor.

5. All living things carry on the processes of nutrition, respiration, circulation, and excretion.

6. All living cells require food and oxygen, and must get rid of carbon dioxide, water, and urea.

BIOLOGICAL TERMS

**abdomen	**gland
**artery	**intestine
**assimilation	**lymph
**bile	**mucus
**blood	**pancreas
**capillary	**pulse
**circulation	**saliva
**corpuscle	**secretion
**diaphragm	**stomach
**digestion	**trachea
**gastric	**urine
**vein	

Applying and Extending What You Know

AS SCIENTISTS WORK AND THINK · **1.** Some persons still believe that fish is a "brain food" and that eating fish will make them more intelligent. Which scientific attitudes[1] are lacking in those who entertain this belief? Relate other superstitions about foods and state which scientific attitudes persons who believe them lack.

2. Fish do not have salivary glands. Whales, seals, and water birds have such glands, but the glands do not secrete saliva. Grain-eating birds have large salivary glands. Cows, when they eat dry feed, secrete many gallons of saliva in a day. What inferences[2] do you draw from these facts?

3. Which elements of scientific method were used by Denis in his experiment on transfusion? Which were not?

4. Which scientific attitudes should one have in considering the statements regarding the use of tobacco in this chapter?

5. Which elements of scientific method and which scientific attitudes are indicated in the account of Lavoisier's experiments on metabolism?

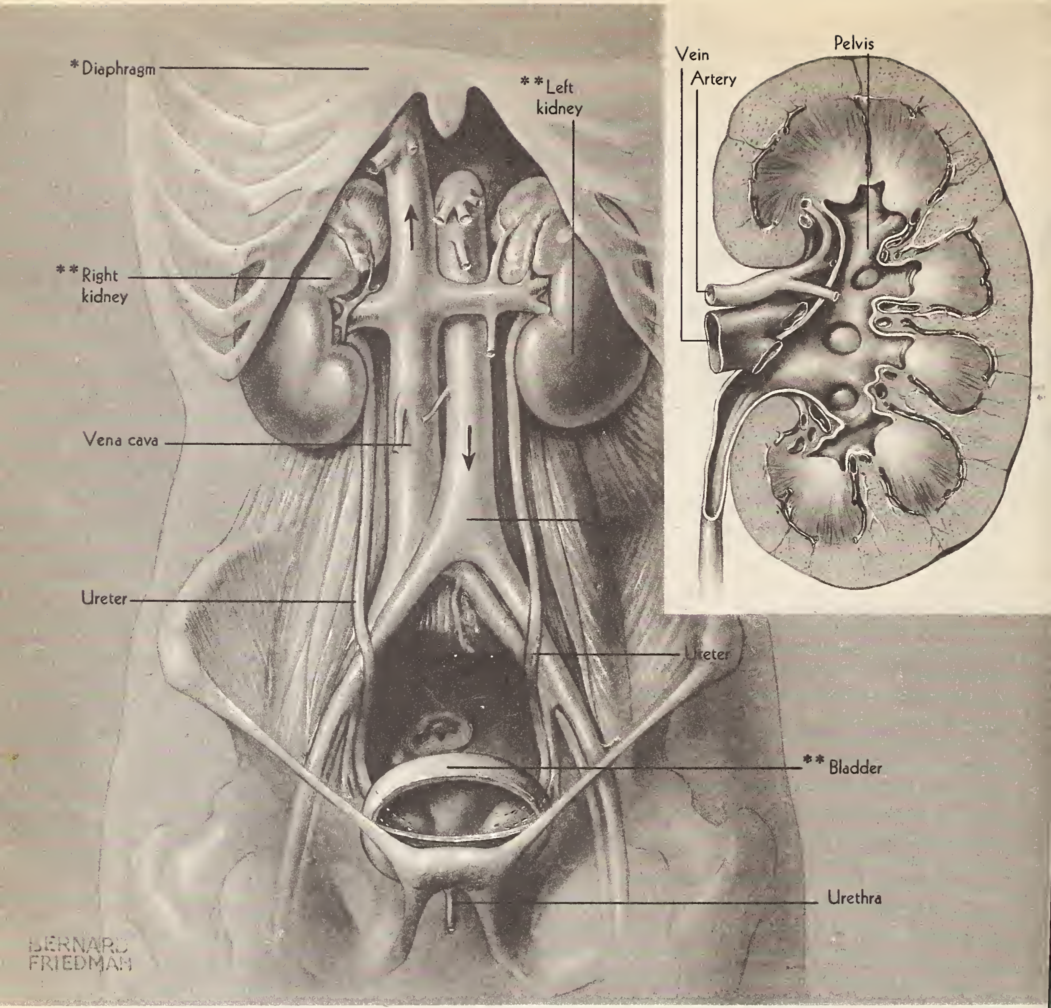
[1]Page 571. [2]Page 570.

6. Less than two hundred years ago "bloodletting," or "bleeding," was a common medicinal practice. The practice consisted in taking considerable quantities of blood from the veins of a sick person. This treatment was based on the belief that sickness causes one's blood to become "bad." Hence it was believed that letting out the "bad" blood would give the body a chance to make "good" blood to replace it. Surgeons even bled persons upon whom they had performed operations or who had suffered accidents from which they had already lost much blood. Well people were bled in the spring and fall in order to make them better able to resist illness.

State reasons why you think that bleeding probably did more harm than good. What scientific attitudes are related to the practice of bleeding?

7. René de Réaumur,[3] a noted French scientist, is believed to have been the first person to discover the effect of gastric juice upon meat. He experimented upon his pet kite, a bird that

[3]René de Réaumur (rẽ nā′dẽ rā ō mūr′). Lived, 1683–1757.



The human kidneys and other excretory organs · How does drinking a sufficient quantity of water help the kidneys to do their work?

casts out from its stomach, through its mouth, all parts of its food that it cannot digest. He caused the bird to swallow short lengths of tubing in the side of which holes had been cut. He had placed small sponges inside the tubes to absorb the gastric juice. When the kite cast out the tubes, Réaumur squeezed out the gastric juice from the sponges. Then he tried the effects of the gastric juice on meat and other substances. What do you think was the real problem which Réaumur started out to solve? He found that the gastric juice dissolved meat. Did he prove that gastric juice digests meat in *our* stomachs? Explain.

CONSUMER BIOLOGY · **1.** Many laxatives are advertised in magazines and newspapers and over the radio. How desirable is the use of specific ones of these? Ask your family doctor for information about them.

2. From the materials on pages 205–221, make up several questions having to do with consumer biology, to be answered or discussed in class.

3. Find out from your nearest hospital what facilities it has for giving transfusions of whole blood, plasma, and blood protein.

APPLYING YOUR KNOWLEDGE OF BIOLOGY · **1.** Give three reasons why food should be chewed thoroughly before it is swallowed. Why should it not be "washed down" with a drink of water, milk, or some other beverage?

2. The windpipe (trachea) of man and some other animals is composed in part of rings of firm cartilage.[1] The esophagus is made entirely of muscle tissue. What might happen if the esophagus were made of cartilage?

3. What kind of tissue makes up most of the digestive system?

4. Why do earthworms leave their burrows during very heavy rains?

5. If a healthy fish is put into water which has been boiled and then cooled, it will die. Why?

6. Why should we be careful, when applying bandages, to make them tight enough, but not too tight?

7. Why do we perspire more on a hot day than on a cold day? Why does exercise cause perspiration?

TOPICS FOR INDIVIDUAL STUDY · **1.** Using a textbook of zoology, make a study of respiration in such animals as amebas, earthworms, insects, fish, frogs, birds, and mammals.

2. In an encyclopedia or some other reference book look up the study which Dr. William Beaumont made of digestion in the stomach of Alexis St. Martin. Describe the various experiments in detail and identify the elements of scientific method which Beaumont used.

3. In an advanced textbook of physiology find the relations between hormones and chalones.

[1]*Cartilage* (kär′tĭ lĭj): a strong, elastic animal tissue.

EXPERIMENTS · **1.** How does a starchy food, such as a cracker, change in flavor as it is chewed? Put a piece of dry, unsalted soda cracker in your mouth and chew it slowly. Let it mix thoroughly with saliva. Does it change in flavor? How do you explain what you have just observed?

2. How does exercise affect the rate of heartbeat? Lie down for a few minutes. Then take your pulse, or have somebody else take it, by counting it for one minute. Make a record of it. Take your pulse again when you are in a sitting position, and again while standing still. Record these rates. Hop as rapidly as you can, 25 times on one foot and then 25 times on the other, without stopping. Take your pulse and record it. Rest for ten minutes; then take your pulse again. When was your pulse rate lowest? When was it highest? Why? Did your pulse rate decrease, remain the same, or increase after the ten-minute rest?

BIOLOGY IN THE NEWS · Watch for and read newspaper or magazine articles describing new discoveries about the human body. Make reports on these articles in your class, your home room, or your science club. Post the articles on the bulletin board.

BOOKS FOR REFERENCE

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Clendening, Logan. *The Human Body* (Revised Edition). Alfred A. Knopf.

Fishbein, Morris. *Your Diet and Your Health.* McGraw-Hill Book Company, Inc.

Graubard, Mark. *Man's Food, Its Rhyme or Reason.* The Macmillan Company.

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Food and Life. United States Department of Agriculture Yearbook (1939).

UNIT FIVE

THE CONQUEST OF DISEASE

What are the nature and effects of important germ and non-germ diseases?

How does the body defend itself against attacks by disease germs?

How is human conservation effected through the prevention and cure of diseases and through accident prevention?

How is human conservation effected through maintaining good mental health?

General Motors Corporation

Why is an illustration of a compound microscope in use an especially suitable one with which to introduce this unit?

11

ENEMIES TO HEALTH

1. What Are the Nature and Effects of Important Germ Diseases?

Some years ago all the members of the crew of a ship which was making a voyage of exploration in the arctic regions became sick with colds at almost the same time. Until this epidemic[1] broke out, there had been no colds aboard the vessel since it had left port, some weeks earlier. How the colds got started was a mystery until it was remembered that a few days before the first cases developed, a rug that was on the floor of the captain's cabin had been taken on deck and beaten. The first men who caught colds had got them from germs[2] which had been on the rug or had been a part of the dust which was beaten out of it. The colds were then spread by germs from these first victims to other members of the crew.

INFECTIOUS DISEASES · Colds belong to the group of infectious, or communicable,[3] diseases. Infectious diseases are those that are "catching." They are caused by germs (illustration, p. 281). Germs that get from a sick plant or animal into the body of a well one either are parasites, mostly microscopic, or are certain non-living substances that cause disease in about the same ways that parasites do. These ways include (1) giving off toxins**[4] (poisons), which become distributed through the host's body; (2) consuming the host's tissues for food; (3) competing with the host for food by consuming food which the host has eaten and digested; and (4) making reproduction by the host impossible.

PLANT AND ANIMAL GERMS · Sometimes we hear people speak of disease germs as "bugs." They will say, "I don't know where I picked up this bug that has made me sick," or they will speak of a "cold bug" or a "pneumonia bug." Such statements are not correct, because bugs are insects, and few insects directly cause diseases. The following pages will tell more completely what germs are and how they cause human diseases. It should be kept in mind, however, that both living and non-living germs of every group hereafter described cause diseases of plants[5] and of other animals, besides man, and that there is probably no living thing, even a bacterium, that is not subject to diseases caused by germs.

PARASITIC FUNGI · **1. Bacteria.** The bacteria are one-celled plants.[6] They are so small that they cannot be seen except through a microscope. Many of them have locomotion.

[1]*Epidemic* (ĕp ĭ dĕm'ĭk): the spread of a disease, rapidly and widely, through a community.

[2]Organisms that cause diseases are commonly called germs, but are technically known as *pathogens* (păth'ō jĕnz) or *pathogenic* (păth ō jĕn'ĭk) *organisms.*

[3]*Communicable* (kŏ mū'nĭ kȧ b'l).

[4]*Toxin* (tŏk'sĭn).

[5]Page 93.

[6]Pages 554–557.

THE GERM THEORY OF DISEASE

IT IS BELIEVED that the first bacteria ever seen were discovered in 1683 by Leeuwenhoek,[1] a Hollander. Leeuwenhoek was a lens-grinder by trade, who studied science merely as a hobby. During his life-time he constructed more than two hundred microscopes. It was with one of these that he discovered bacteria. Because of this and other discoveries, he is now honored as one of the greatest naturalists of all time.

Always, when a scientist announces a discovery, many other scientists check that discovery. Therefore, after Leeuwenhoek's description of bacteria had been published, many other scientists searched for and found bacteria of various kinds. But they all thought of the bacteria as being merely strange and interesting organisms. It did not occur to any of these scientists that bacteria could in any way affect man's welfare.

As early as the sixteenth century an Italian doctor, Fracastoro,[2] suggested that some diseases are caused by living "seeds of disease" which pass from sick to well people. Other scientists, from time to time, contributed to the theory that some diseases are communicable. But no one connected bacteria with diseases until about 1870.

At that time Pasteur,[3] a noted French scientist, discovered that a bacterium was the cause of a silk-worm disease that was about to destroy the French silk industry. Later he proved that anthrax in sheep was likewise caused by a bacterium. These discoveries by Pasteur were of major importance in establishing the germ theory of disease. The germ theory of disease is that diseases of many kinds are spread from sick to well plants and animals by micro-organisms, or microbes.

The next great milestone in the progress toward establishing the germ theory was the work of a German, Koch.[4] Koch was a country doctor with a great interest in experimenting. When he was twenty-eight years old, he attacked the problem of the cause of anthrax in cattle and sheep. In his experimenting he used the new microscope that his wife had given him as a birthday present. He discovered that the blood of animals sick with anthrax contained innumerable anthrax bacteria, but that the blood of well ones contained none. When he injected the blood from sick animals into well ones, the latter soon became sick with anthrax. These facts led Koch to infer that the bacteria were the cause of the disease. But he had to make sure that they were.

He secured a mouse that had just died of anthrax. He secured also some fluid from the eye of a cow that had been killed for meat. This eye fluid contained no bacteria, but it would serve as an excellent culture for bacteria. Also, it was clear and hence could easily be studied with a microscope.

Koch added a minute drop of the mouse's blood to a large drop of the eye fluid. The bacteria multiplied rapidly in the fluid. After a day or so, he infected a fresh drop of the fluid with a minute drop of the culture. In the same way he made a series of cultures,

[1]*Leeuwenhoek* (lā'vĕn ho͞ok). Lived, 1632–1723.
[2]*Fracastoro* (frä kä stô'rō). Lived, 1483–1553.
[3]*Pasteur* (päs tûr'). Lived, 1822–1895.
[4]*Koch* (kōk). Lived, 1843–1910.



Metropolitan Life Insurance Company

Louis Pasteur and Robert Koch · Which of the scientific attitudes, and which of the elements of scientific method, can you identify in this account of the work of Pasteur and Koch?

preparing each new one from the preceding one. Finally he had what he was sure was a pure culture, that is, a substance in which only one kind of micro-organism is living.

Next he dipped a clean splinter into this culture and inoculated a healthy mouse with the bacteria by sticking the point of the splinter under the mouse's skin. The mouse soon became ill and died of a disease which seemed certainly to be anthrax.

There was a slight chance that the eye fluid, and not the bacteria in it, might have caused the mouse's death. This possibility had to be tested. To test it, Koch set up controls by inoculating several healthy mice with fresh eye fluid containing no bacteria. This he did in the same way that he had inoculated, with the culture, the mouse that later died. Not one of these mice became ill.

Koch performed many more check experiments by repeating all the steps described. Always he secured the same results.

From this careful work Koch reached the only conclusion possible, namely, that anthrax is caused by bacteria. Later, from experiments much like those just described, he proved that tuberculosis in people is caused by a certain kind of bacillus. Thus he was the first scientist to establish the fact that at least one human disease is caused by bacterial germs.

In 1882 Koch announced the following steps of his method of finding the cause of a germ disease: (1) Examine the blood or other structures of sick and well animals or people until you find some organism in the sick ones that is not found in the well ones. (2) Make a pure culture of that organism. (3) Inoculate healthy individuals with this pure culture. (4) If they become sick with the disease, examine their blood or other tissues to see whether these structures contain the organism. If they do, there can be little doubt that that particular organism is the cause of the disease.

Koch's method is a standard one today in the study of the causes of diseases.

Because of this, they were believed to be animals until about a century ago. There are thousands of species of them. They live practically everywhere. Countless numbers inhabit the soil, the oceans, and the rivers and other bodies of fresh water. They have been found in the stratosphere and also in freshly fallen snow near the south pole. Most kinds are harmless, and some are useful.[1] Only a relatively few kinds cause diseases.

Bacteria are classified into three groups according to their shapes (illustration, p. 281): (1) the rod-shaped bacteria (bacilli[2]), (2) the ball-shaped bacteria (cocci[3]), and (3) the spiral-shaped bacteria (spirilla[4]).

2. Molds. Relatively few kinds of molds are parasites of people; yet some can cause serious infections. Some years ago, for example, newspapers carried an account of a woman who nearly died from the attack of a mold which she found growing on a pair of her old shoes. In trying to get the mold off the shoes, she had breathed in its spores.**[5] This particular mold was able to live both as a parasite in her lung tissues and as a saprophyte on the shoe leather.

Common fungus diseases of people include athlete's foot and ringworm. Dhobie itch, a fungus disease, greatly annoyed our armed forces in the tropics during the Second World War. There are also a number of fungus diseases that attack domestic animals. Perhaps you have seen goldfish that have been attacked and killed by mold parasites which appear as white patches on their bodies.

PARASITIC ANIMALS · **1. Protozoa.** Although relatively few kinds of protozoans cause human diseases, the diseases which protozoans do cause are among the most serious of all. Perhaps the best-known of these diseases is malaria.

Like many other parasites, the malarial germ requires two hosts alternately in order to complete its life cycle. Thus it must live part of its life in a person, a horse, a cow, or one of a few other kinds of animals, and the other part in a certain genus of mosquito (*Anopheles*[6]).

When one of these mosquitoes[7] bites a person who is ill with malaria, some of the malarial parasites are taken into the mosquito's body, along with the person's blood. Thus the mosquito becomes infected with the malarial germs from the person. The malarial parasite goes through certain stages of its development in the mosquito's body and finally reaches the stage in which it can again infect a human being (illustration, p. 282).

If then the mosquito bites a person, in doing so it injects[8] some of the parasites, along with its saliva, into the person's blood. Thus the person becomes infected with the malarial germs from the mosquito. The germs bore into the person's red corpuscles, or red blood cells. There they continue their development (illustrations, pp. 250, 429). The results make the human host sick with malaria.

After a few days in its human host the parasite again reaches the stage of its life cycle in which it can infect a mosquito of the right

[1]Pages 96–99.

[2]*Bacilli* (bȧ sĭl'ī); singular, *bacillus* (bȧ sĭl'ŭs).

[3]*Cocci* (kŏk'sī); singular, *coccus* (kŏk'ŭs).

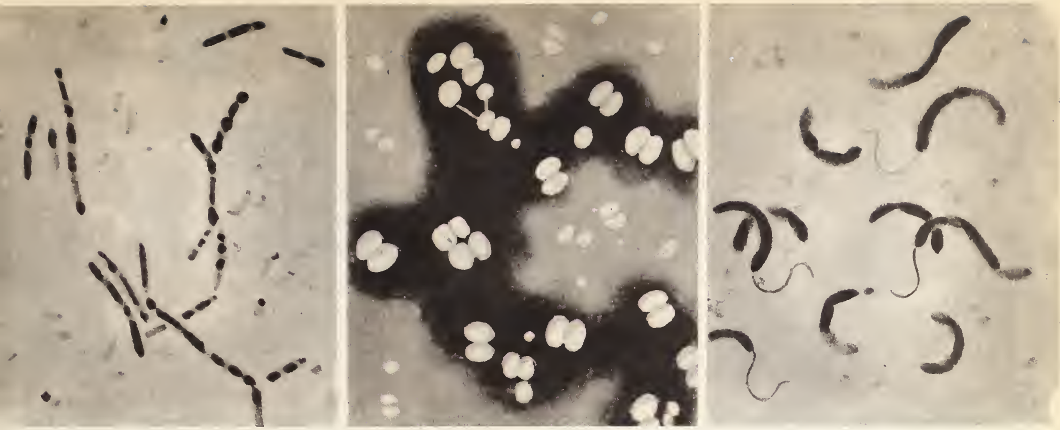
[4]*Spirilla* (spī rĭl'ȧ); singular, *spirillum* (spī rĭl'ŭm).

[5]*Spore* (spōr): a cell that can develop into a plant or an animal of the same kind as that which produced it. Mold spores float about in the air as part of the dust.

[6]*Anopheles* (ȧ nŏf'ē̤ lēz).

[7]An organism that carries and transmits disease-causing micro-organisms is called a *vector* (vĕk'tẽr). The most common vectors are insects.

[8]*Inject:* to force into—as a liquid into some part of the body, usually with a hypodermic syringe. *Injection* (ĭn jĕk'shŭn): the act of injecting; the substance injected.



Westinghouse Electric and Manufacturing Company

Types of bacteria · Familiar human diseases that are caused by bacterial parasites include tuberculosis, typhoid, diphtheria, whooping cough, and scarlet fever. There are more disease germs dangerous to man among the rod-shaped bacteria (the bacilli) than among the ball-shaped (cocci) or the spiral ones (spirilla). How many human diseases can you name which you know are infectious?

kind. If such a mosquito bites the malaria patient, the "mosquito phase" of the parasite's life cycle develops. Thus the cycle is repeated endlessly.

If a parasite such as the malarial germ, which requires alternate hosts, fails to get into the right kind of animal to serve as its host, at the right time, in either state of its life cycle, it dies.

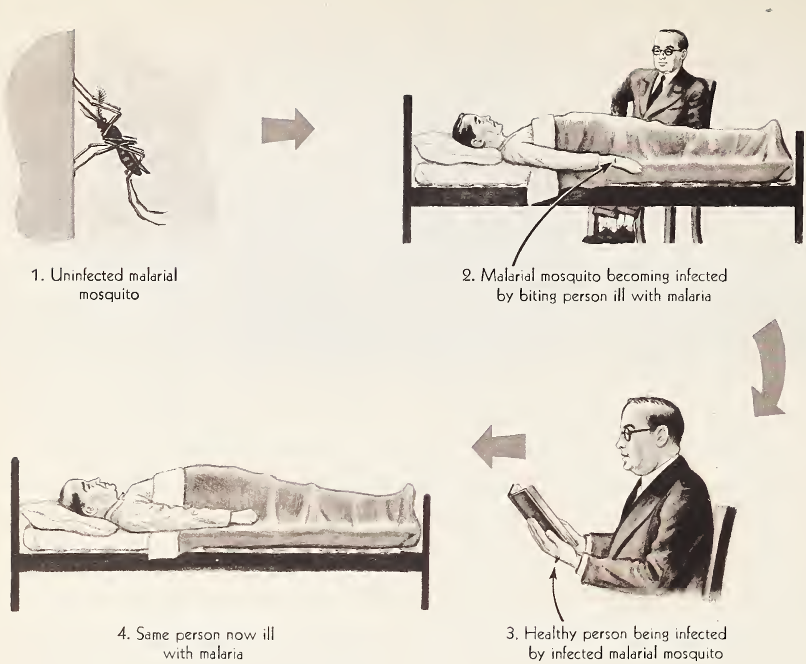
Amebic dysentery is a dangerous malady which is caused by certain species of parasitic amebas. These require only one host, which can be a human being. They develop in the human intestines. The disease is commonly spread when the germs in the intestinal wastes of people having the disease get into the water supply, or when the germs from the hands of those sick with the disease get into food. In many tropical countries where sanitation is bad, it is not safe to eat raw vegetables, because the vegetables may have become contaminated in one or both of the two ways just stated.

African sleeping sickness is another formidable disease that is caused by a parasitic protozoan (illustration, p. 250). This germ requires alternate hosts and is introduced into man and some other animal by the bite of a certain kind of fly (tsetse[1] fly).

2. Round worms. Some years ago the newspapers of a Western city carried a tragic story. Two members of a family had died from trichinosis.[2] Five others had become seriously ill with this disease. They had contracted it from eating sandwiches made with partly cooked pork. The parasitic roundworms[3] that caused the disease were in the pork. Only the baby of the family escaped, and it did so because it was too young to eat the infected meat.

Nearly fifty species of roundworms are known to live in man. Most of them neither benefit nor harm him.[3] A few, however, are dangerous enemies. Common ones of the

[1] *Tsetse* (tsĕt′sē). [2] *Trichinosis* (trĭk ĭ nō′sĭs).
[3] Page 522.



The life cycle of the malarial parasite · An organism, usually an insect, that carries and transmits disease germs to new hosts, and thus spreads disease, is known as a vector.[1] What is the vector of malarial germs?

latter are the trichinosis and the hookworm parasites. In some tropical countries almost all the natives have hookworm disease, and in some sections of the Southern states many of the poorer people suffer from it.

Trichinosis parasite. Like the protozoan that causes malaria, the trichinosis parasite must have alternate hosts (illustration, p. 283). It can live part of its life in a pig, a rat, a mouse, a cat, a bear, and a few other mammals. At the end of that half of its life cycle, it burrows into the flesh of its host and forms a cyst.[2] It then dies unless the flesh containing it is eaten by one of the animals that can serve it as a host for the second half of its life cycle.

Man is one of several animals that can serve as suitable hosts in which the parasite may complete its adult state. Once eaten along with infected meat (usually pork), the trichinosis parasite multiplies enormously in the second host. The young worms by the

[1] *Vector* (vĕk′tẽr).

[2] *Cyst* (sĭst): a small organism, usually in a dormant state, enclosed in a protective wall; also, the wall that encloses and protects such an organism. An animal thus enclosed is said to be *encysted* (ĕn sĭs′tĕd).

thousands get into the blood stream and are carried to all parts of the body. They bore into the muscles, making them red, swollen, and intensely painful.

Trichinosis is one of the most common of all diseases. One American out of every six is said by medical authorities to be more or less seriously infected with trichinosis worms. Fortunately, however, this disease is not often fatal. There is no danger whatever of contracting trichinosis if the meat that might contain the parasites has been thoroughly cooked. Thus pork should be cooked until the meat is no longer pink, but is white all through.

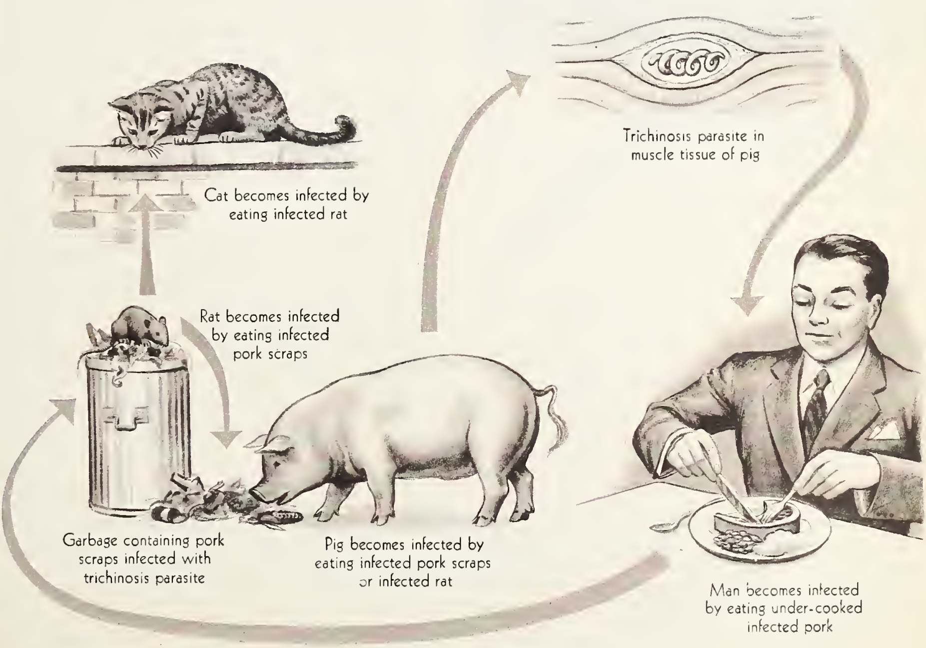
Recent experiments indicate that the trichinosis parasites in pork can be killed by refrigerating the meat at a temperature of about thirty-two degrees below zero Fahrenheit (—32° F).

Hookworm. Unlike the malarial and trichinosis parasites, the hookworm can complete its entire life cycle in the body of one animal. It passes out with the excreta. It can remain alive for some time in soil. Hence it commonly enters a person's body from contaminated soil, through the skin of any part of the body. Hookworm disease is certain to be common in localities where hookworm parasites infest[1] the soil and people go barefoot.

This parasite weakens its host by sucking

[1] *Infest* (ĭn fĕst′): to occupy in great numbers.

The life history of the trichinosis parasite (Trichinella) · If a cat contracted trichinosis from eating an infected mouse, could people become infected with trichinosis by the cat? Explain



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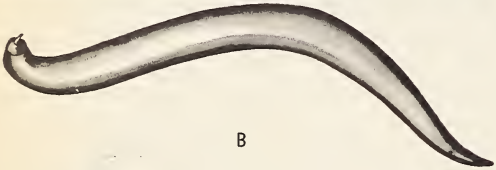


B

A. Rockefeller Foundation

A. These two people are of the same age. The larger one is normal. The smaller one is suffering from hookworm disease, which often causes its victims to be under-sized.

B. Hookworms can be seen with the naked eye and look like tiny white hairs. Compare the life habits of the hookworm and trichinosis parasites, stating ways in which they are alike and ways in which they are different

its blood and by causing internal wounds that do not readily heal (illustration on this page). Thus it saps the energy of its victim, not only making him unable to work or to enter into other activities, but also making him an easier prey to the germs of tuberculosis and of other diseases.

Danger from the hookworm parasite can be practically removed by preventing the soil from becoming contaminated with excreta. Wearing shoes reduces the chances of infection by preventing the hookworms from entering through the feet.

Filariasis. Another parasitic roundworm causes a certain disease of the lymphatic system. This disease (filariasis[1]) is fairly common in many tropical regions. Like the germ that causes malaria, the parasite is introduced into a person's body through the bite of a certain kind of mosquito. The roundworms clog the lymph glands and thus shut off the lymph circulation. As a result, there is an abnormal swelling of the part of the body affected. Sometimes an arm will become as large as a leg, or a leg will become as large as the body. A person can more or less completely recover from this disease if he is not reinfected.

3. Flatworms. There are at least six kinds of tapeworms and eight kinds of flukes[2] that are common and dangerous parasites of man in many parts of the world. They live in various organs of their hosts, such as the muscles, the liver, the intestines, the brain, and the eyes, or they live in the blood stream. All require alternate hosts in order to complete their life cycles.

Tapeworm. The common tapeworm is the most familiar parasite of the flatworms. The tapeworm eggs sometimes get into drinking water and on the food of animals, usually from

[1]*Filariasis* (fĭl *á* rī'*á* sĭs). [2]Page 285.

excreta. If an egg happens to be swallowed by a fresh-water shrimp or fish, or by a fox, rat, mouse, cow, sheep, pig, or other animal inside which a young tapeworm can live, the parasite completes the first part of its life in the body of that animal. If the raw or rare flesh of that host, containing the young tapeworm, happens to be eaten by any one of several flesh-eating mammals, including man, the tapeworm completes its life cycle in this second host.

The common tapeworm attains its ribbon-like form only in its second host. Its "head" becomes attached to the intestine wall, and new sections of the worm are added, one after another, behind the head. In this way the tapeworm sometimes becomes more than thirty feet long.

In the Orient and in Africa, raw fish is a common item of the diet. Hence people frequently become infested with tapeworm and other dangerous parasitic flatworms that use the fish for their first, or intermediate, hosts.

The common tapeworm injures its human host by the third method stated on page 286. It absorbs the digested food in its host's intestines.

Parasitic flukes.[1] Did you ever have "water itch," or "swimmer's itch"? It is an intensely uncomfortable, but not dangerous, condition that is caused by certain flatworm parasites. If you have bathed in some of the lakes of the northern Middle Western states or of the central Canadian provinces, you may have found your body spotted with what looked and felt like severe mosquito or chigger bites, within twenty-four hours after you had been in the water.

The spots of swimmer's itch are caused by the young of one or more of four different species of flatworms. These parasites use water snails for their first hosts and muskrats and certain kinds of water birds for their second hosts. When the worms are ready for a second host, they will bore into the skins of people in the water, just as readily as they would into the skins of muskrats and water birds. But man is not a suitable host. The flukes cannot continue to develop in human beings. Hence they die. Their dead bodies under the skin cause the severe itching, which lasts usually for several days but occasionally for weeks.

There are many serious diseases in the Far East, caused by flukes that live in the water. These parasitic flatworms bore into the legs of people when the latter are wading in the water, planting rice.

"BORDER-LINE" GERMS · **1. Viruses.** The human diseases caused by viruses are numerous. They include colds, influenza, smallpox, measles, yellow fever, rabies, and infantile paralysis. The virus germs range in size from those too small to be seen with any microscope except an electron microscope,[2] to others that are larger than the smallest bacterial germs.[3]

2. Rickettsiae. The germs of Rocky Mountain spotted fever, typhus fever, and several other serious diseases are rickettsiae.[4] Scientists do not yet know the true nature of these germs. The evidence thus far available indicates that rickettsiae are not truly living organisms, but that they may be more nearly like one-celled organisms than are viruses.

HOW INFECTIOUS DISEASES ARE CONTRACTED · Several common ways in which people may become infected with disease germs have been described in the preceding

[1]Page 521.

[2]Page 404. [3]Page 277.

[4]*Rickettsiae* (rĭk ĕt'sĭ ē).

discussions of germs. These ways and some others are summarized in the following paragraphs. Usually the same disease can be contracted in more than one of these ways.

1. **Getting the germs by breathing the breath of a sick person or by breathing the air into which a sick person has sneezed or coughed (illustration below).** A person's breath and the air for several feet in front of a person who has sneezed or coughed is filled with tiny drops of saliva. The drops in the air around people sick with colds, tuberculosis, diphtheria, and many other diseases contain the germs of these diseases.

2. **Getting the germs from objects that a sick person has handled or used.** A person with an infectious disease gets the germs on his hands from his nose, mouth, or other infected part. He leaves live germs on the things he touches, and these germs get on the hands of other people who touch these objects. The germs may then get from the hands of the latter to parts of their bodies which the germs are able successfully to attack. Most of the diseases that can be contracted by breathing germ-filled air can be contracted also in the way just described.

3. **Getting the germs by touching people or handling animals that have the disease.** Tuberculosis and colds are examples of the many diseases that may be contracted by kissing. Ringworm and "rabbit fever" (tularemia) are diseases that can be contracted from handling animals that are infected with the germs.

4. **Taking in the germs with drinking water or with foods.** Tuberculosis, typhoid, cholera, dysentery, tapeworm disease, and

What socially desirable practice is illustrated here? Explain

numerous other diseases can be contracted from drinking water that has been contaminated with germs in excreta. Milk and other foods are often contaminated with the germs of many of these and other serious diseases from the hands and breath of sick people. Food is readily contaminated, too, by germs carried on the feet and bodies of flies, cockroaches, and other insects that thrive in filthy places.

5. Getting the germs from the bites of infected arthropods or other organisms. As has been stated, malaria and filariasis germs are introduced into our bodies by the bites of infected mosquitoes, as are also the germs of yellow fever. Other disease germs transmitted by the bites of infected arthropods are those of Rocky Mountain spotted fever, by ticks; typhus, by lice; and sleeping sickness, by tsetse flies (illustration, p. 250).

HOW INFECTIOUS DISEASES ARE SPREAD · Diseases are spread within a community in all the ways just discussed. Often, however, we hear about a "new" disease or about an outbreak of a familiar one in a locality where it has not been known before, or where it has not existed for some time. In such cases the germs are introduced into the new region usually by one of the following means:

1. Human carriers. A person actually sick with an infectious disease is a carrier, of course. He can infect others wherever he goes. But there are other types of human carriers. One is a person who has live germs in his body, but who either has recovered from the disease or has been able to resist its attacks and thus has not been made sick by it. He can often transmit the disease to other people by one or more of the methods described on the preceding pages.[1]

Every infectious disease has an incubation period. This period begins when the germs enter one's body and ends when one becomes sick with the disease. It varies, with different diseases, from a few hours to two weeks or longer. If the incubation period is long, a person can travel a long distance between the time when he becomes infected with the germs and the time when he actually becomes ill. To illustrate, there are many instances in which a person, after having been exposed to smallpox, diphtheria, or other infectious disease, has gone to another town or another state or province, where he became sick and started an epidemic of the disease.

The airplane has greatly increased the danger from human carriers of disease. With modern rapid airplane travel a person could be exposed to bubonic plague and yellow fever in Asia and could reach the United States or Canada during the incubation period of the disease.

2. Arthropod carriers. Ticks and lice that are infected with disease germs may be brought into new localities. For example, Rocky Mountain spotted fever is no longer found only in certain parts of the West. Occasional cases have been discovered in nearly all the states. In most instances the infected ticks were probably spread to the new sections by automobile travel. A few years ago mosquito hosts of the African malaria germ were brought by airplane to Brazil. There they started a serious epidemic.

3. Other animal carriers. Domestic animals or pets having germ diseases that can be contracted by human beings are sometimes brought from one part of the world to another and thus introduce the diseases there. For example, an outbreak of parrot fever (psittacosis[2]) which occurred some years ago in the United States was caused by infected parrots brought from the tropics.

[1]Some authorities consider only this latter kind of person to be a human *carrier* of disease.

[2]*Psittacosis* (sĭt *ȧ* kō′sĭs).

Bristol Brass Corporat

Ringing the dinner bell on a farm about fifty years ago • Note the dipper in the water pail and the towel, which all used. Which of the ways in which diseases are contracted are indicated by these and other objects shown here?

Diseases often spread rapidly after being introduced into a new locality because the germs find there native animals that can serve as their hosts. These new hosts not only give the germs a foot-hold in the new region, but also multiply their opportunities to cause infection. For example, Canada and the United States have many native insects that are suitable alternate hosts (vectors) to spread insect-carried germs that might be brought in from other parts of the world. An instance of the spread of a "new" disease is furnished by undulant fever. This was originally known as a disease of goats. After some infected goats had been introduced into the United States, undulant fever soon became a serious disease of cattle and, occasionally, of human beings.

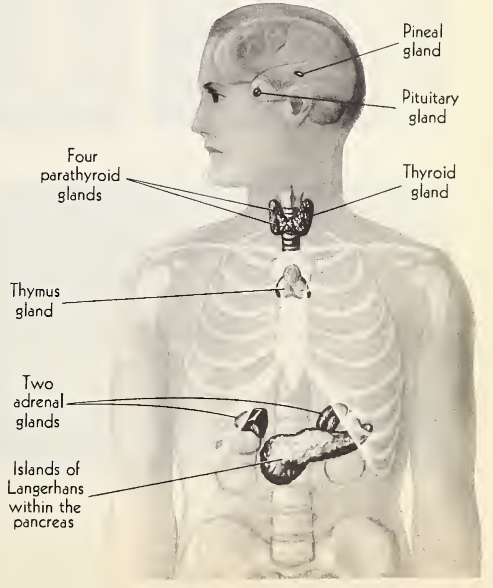
Post-war problems. [E]The facts presented in this section show clearly that the spread of diseases is not a matter of merely local concern. It is a world-wide problem. The Second World War made people more conscious than ever before that a disease in any part of the world is a source of danger in all other parts. A major problem of every nation in the post-war period is to help to combat diseases wherever they are found, to prevent their spread to other countries, and, if possible, to stamp them out wherever they exist. Great progress has already been made toward the solution of this world-wide problem

2. *What Are the Nature and Effects of Important Non-germ Diseases?*

We hear so much about germs and germ diseases that we are likely to think that the most common and serious ailments are caused by germs. In the United States and Canada the opposite is nearer the truth. High blood pressure, a non-germ disease, causes more deaths than any other disorder. Diseases of the heart rank second, and cancer ranks third, from the point of view of the number of deaths that they cause. Diseases of the heart claim the lives of more than twice as many people as cancer. Cancer annually causes more than twice as many deaths in the United States as the three most deadly germ diseases combined, namely, influenza, pneumonia, and tuberculosis.

CAUSES OF NON-GERM, OR NON-INFECTIOUS, DISEASES · Some non-germ diseases are due to the failure of certain ductless, or endocrine, glands to function properly. Others occur when essential substances are lacking in our foods. Still others result when people eat certain foods which are highly injurious to them, though the foods are wholesome to most other people. Others, again, are contracted from breathing pollens and other substances that make up dust. Still others can be traced to chemical fumes and to poisons taken in small quantities along with food. Another group is made up of organic diseases, and still another of diseases resulting from aviation.

The endocrine glands · How do you infer that the hormones pass through the walls of the endocrine glands? Look up in the Index all references to the ductless glands and prepare a discussion of the functions of each

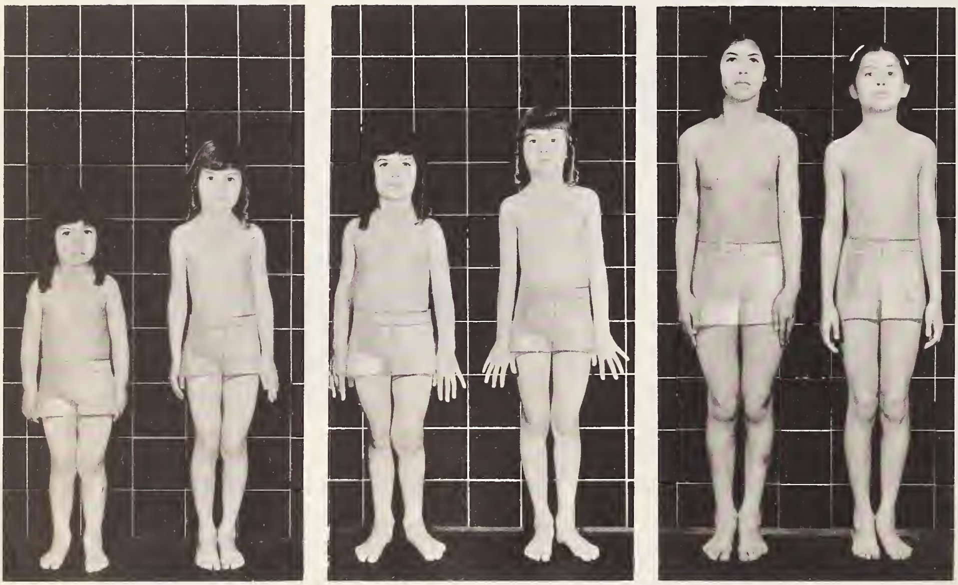


1. Diseases and other abnormal conditions caused by improperly functioning endocrine glands (illustration, p. 289). The ductless glands[1] together make up an organ-system. All the various glands in this system must function together in harmony in order that an individual may be normal and healthy. Whenever this glandular system is disturbed so that one of the glands secretes too much or too little of its special hormones, abnormal conditions follow. The body as a whole, or parts of it, may grow too rapidly or too slowly; the intelligence may be affected;

[1]Page 232.

10-year old patient | 6-year old normal sister | 18 months later | 5 years later

E. Kost Shelton and *Endocrinology*



H. R. Basinger and *The Archives of Internal Medicine*

Above, a cretin girl and her normal sister; below, a normal rabbit and two cretin rabbits, all from the same litter and twelve weeks old · The cretin girl was enabled to develop normally by means of thyroid extract prescribed by her physician. **Topic for Individual Study:** Find out from your local druggist or your family physician how hormones are administered

the behavior may become abnormal; or diseases may result.

The thyroid[1] *gland.* Perhaps you have seen a person with a goiter. Simple goiter is a swelling in the front of the neck at its base. It results when the thyroid gland fails to produce a sufficient supply of a certain hormone (thyroxine[2]). This hormone plays an important part in the control of metabolism.

Though its cause is not yet known beyond question, simple goiter is generally considered to be a deficiency disease, due to a hidden hunger.[3] The hormone (thyroxine) is composed mostly of the element iodine. If, according to most authorities, the diet does not supply enough iodine for building this hormone, the thyroid gland swells, and this swelling is the goiter.

Sometimes a child is born with a defective thyroid gland, or this gland becomes defective soon after birth. In this case the thyroid gland secretes too little of the important hormone, even though the diet contains enough iodine. As a result, the rate of the child's metabolism is below normal. Hence not enough energy food is changed in its body cells to permit its normal development. Consequently the child is dull-minded and inactive. It is slow of growth and may be permanently dwarfed. Such a child has a characteristic appearance and is known as a *cretin*[4] (illustration, p. 290).

In rare cases the thyroid gland of an adult wastes away somewhat, or otherwise becomes defective. The result is a serious disease (myxedema[5]). With this disease the patient's skin becomes thick, his hair falls out, his body becomes puffy, his physical and mental vigor are greatly reduced, and he has difficulty in keeping warm.

[1]*Thyroid* (thī′roid). [2]*Thyroxine* (thī rŏk′sēn).
[3]Pages 92–94. [4]*Cretin* (krē′tĭn).
[5]*Myxedema* (mĭk sē dē′mȧ).

In contrast with the conditions described above, in some cases the thyroid gland becomes over-developed and produces too much of its hormones. The result may be a second type of goiter (exophthalmic[6] goiter). In this case the swelling at the base of the neck is often less noticeable than that in simple goiter, because it is chiefly internal. As one would expect, the effects of this disease are largely the opposite of those which result from lack of the hormone. The person with the disease is more than normally active, becomes thin though he eats much, and is likely to feel too warm.

Simple goiter can, in most cases, be prevented by using "iodized salt," which is ordinary table salt to which a small amount of an iodine compound (potassium iodide) has been added. For example, in 1925, in one of the Middle Western states, 36 per cent of the school children had goiter. By 1937, however, when the use of iodized salt had become general only 1 per cent had goiter.

An extract made from the thyroid glands of pigs, sheep, and other mammals is often given by doctors, with beneficial results, to persons who need more of the hormone than their thyroid glands produce, or to persons who have a disease (cretinism or myxedema) resulting from a serious lack of the hormone.

The second type of goiter is often successfully treated by surgery. The surgeon removes a part of the thyroid gland, thus reducing the supply of the hormone.

Fortunately, all the mammals have glands enough alike so that hormones which their glands secrete will cause in man the same effects as are produced by his own hormones. Hence most of the glandular extracts used in making up not only deficiencies of hormones produced by the thyroid gland, but also those of hormones secreted by other glands, are

[6]*Exophthalmic* (ĕk sŏf thăl′mĭk).

prepared from the corresponding glands of animals which are butchered for meat. These extracts are often successful in making patients more nearly normal. But they do not cause the defective glands to function normally. They merely make up for the lack of the hormones which the glands should supply. Usually a patient must continue to take a glandular extract during the rest of his life.

The parathyroid[1] *glands.* Without the normal amounts of the hormones secreted by these four small glands (illustration, p. 289), the bones and teeth will not develop normally. The reason is that these hormones bring about the assimilation of phosphorus and calcium, which are essential in bones and teeth. These hormones also affect muscular control and the functioning of the nervous system.

The adrenal[2] *glands.* The hormones of these two glands are important in normal growth and development. They function also in controlling metabolism.

The thymus[3] *and pineal*[4] *glands.* Little is yet known about these glands. It is believed that the hormones of both may affect progress toward maturity.

The pituitary[5] *gland.* Whether you are going to be of normal height or unusually large or unusually small depends on hormones secreted by the pituitary gland. Too much of one of its hormones may result in a sideshow giant. Too little may result in a midget (illustration, p. 293). Too little of one of its hormones may cause a person to become very fat or to be feeble-minded. Another of its hormones is believed to control the functioning of the kidneys. Certain of its hormones are believed to regulate and control the functioning of other glands.

[1]*Parathyroid* (păr *a* thī′roid). [2]*Adrenal* (ăd rē′năl).
[3]*Thymus* (thī′mŭs). [4]*Pineal* (pĭn′ē ăl).
[5]*Pituitary* (pĭ tū′ĭ tĕr ĭ).

Endocrine glands within the sex glands. Within the sex glands are small groups of cells that are not related to reproduction. These cell masses are endocrine glands. Their hormones are essential to normal growth and development and hence are closely related to those of the pituitary gland. They begin to function actively at about the beginning of adolescence, that is, the period of life during which an individual develops from a child into a mature man or woman. The hormones of these glands control the development of the male and female characteristics—for example, the beard and the pitch of the voice.

Pancreatic glands. The ductless glands (known as the islands of Langerhans) within the pancreas produce an important hormone, insulin*[6] (illustration, p. 289). Insulin regulates the body's use of sugar. With some people the pancreas fails to produce enough insulin. As a result, the liver is unable to perform its function of taking surplus sugar from the blood and storing it as glycogen (animal starch) in its tissues. Nevertheless the sugar produced by digestion continues to be added to the blood. At the same time the body cells, without sufficient insulin, are unable to take out of the blood the sugar that they constantly need as food. Moreover, the kidneys must work harder than usual to remove the extra sugar from the blood. All these and other conditions result in the disease called diabetes.[7]

Formerly diabetes was nearly always fatal. Until recently, only the mild cases could be controlled, and then only by leaving out of the diet most of the foods that produce sugar. In 1922, however, two Canadian scientists, Banting and Best, by applying the results of a long series of experiments with dogs and other animals, invented a way of preventing and treating diabetes. This treatment consists in

[6]*Insulin* (ĭn′sū lĭn). [7]*Diabetes* (dī *a* bē′tēz).

injecting insulin into the blood. When a patient is thus supplied with sufficient insulin, he is able to go about his business almost as freely and effectively as a normal person. Insulin, however, does not effect a cure. The patient must continue to take insulin as long as he lives.

2. A disease caused by growths: cancer. Cancer is one of the oldest known diseases. There are references to it in the Old Testament, as well as in some of the early writings of India. Ancient Greek and Roman writings also contain references to this terrible disease.

Cancer is an abnormal growth of tissue. Its exact cause or causes have not yet been determined, but it is known to start in a cell or in a small group of cells. It grows at a rapid rate, spreading through the surrounding tissues. Finally it grows through the walls of the blood vessels and lymph vessels. Separate cells break off from the mass and are carried by the blood stream to other parts of the body. There they develop new cancers.

Cancer attacks people of all ages, but older people somewhat more often than those under twenty. It kills nearly two hundred thousand people every year in the United States and Canada. Yet half of these deaths could probably be prevented if everybody knew the more easily recognized symtoms[1] of cancer and would consult a medical doctor immediately upon discovering one of the dangerous symptoms in himself. These symptoms are

1. A painless lump that does not go away, in any part of the body, but especially in the breast. Not all such lumps are cancers. Most of them are harmless, but some that are harmless in their early stages develop into cancers later.

[1]*Symptom* (sĭmp′tŭm): any change in the condition of the body that indicates sickness.

Press Association

During the Second World War midgets rendered especially valuable service in airplane-manufacturing plants because they were able to work effectively inside airplane wings and in other places where normal-sized persons could not. What do you think is the chief value of such an illustration as this?

2. A sore that does not heal, especially one on the face, about the mouth or on the lips.

3. An unnatural blood-stained discharge from any natural body opening.

4. Indigestion that continues, especially if one changes weight and has a change of appetite while it persists.

5. Any change in the normal bowel habits.

6. A sudden change in the size, color, or shape of a mole or a wart.

7. A chronic hoarseness, an unexplained cough, or a chronic difficulty in swallowing.

Have you heard of "farmer's cancer" and "sailor's cancer"? These are terms well known to dermatologists.[1] Such cancers are known to result sometimes from exposing the skin too much to sunshine (illustration below). Cancers resulting from over-exposure to sunshine, however, are relatively rare.

No ointments or other medicines will cure cancer. Doctors, however, can often remove or destroy the dangerous growths by surgery, X rays, or radium. Radio-active gold, obtained as one product of "atom-smashing," has proved more effective than X rays in treating some kinds of cancers (illustration, p. 148). But doctors can effect cures in one of these ways only if the surgery is performed or the treatment is begun in an early stage of the disease.

3. Diseases caused by a lack of essential substances in the diet. Among the most terrible effects of the Second World War in conquered countries have been deficiency

[1]*Dermatologist* (dûr mȧ tŏl′ō jĭst): a doctor who is a specialist in diseases of the skin.

[E]Sunshine is one source of vitamin D. Some exposure of the body to sunshine is healthful. Too much may prove harmful. Avoid sunburn. Not only is it painful, but it sometimes has serious results. What outdoor activity is suggested in this picture?

West Michigan Tourist and Resort Association

diseases.[1] The destruction of farms and orchards in the battle areas, the taking of foods by the conquerors from the conquered peoples, and the impossibility of importing foods from other countries have resulted in almost universal malnutrition in the conquered lands. Deficiency diseases resulting from a lack of vitamins have become so widespread and so serious that the nations affected may not entirely recover for generations.

Deficiency diseases are not ailments that occur only in wartime or only in conquered countries. It was found that 3.2 per cent of the men who were drafted for the armed forces of the United States, during the Second World War, had deficiency diseases. These were chiefly diseases known to be due to a lack of vitamins. Forty-three per cent had other defects which also might have been due to a lack of vitamins. All the deficiency diseases cause great suffering and many deaths.

Vitamin deficiencies. Each of several vitamins is already associated with one or more diseases which result only when that particular vitamin is lacking. As more is discovered about vitamins, more definite and complete knowledge of the relation of vitamins to diseases can be expected. Only a few of the more serious diseases due to certain vitamin deficiencies can be considered here. The sources of the various vitamins are discussed in another part of this book.[2]

Rickets is common, in more or less severe form, almost everywhere. It results usually from a lack of vitamin D. Without this vitamin the body cannot use calcium and phosphorus to build strong bony structures. Without it, therefore, the bones and teeth do not develop properly, and consequently are often deformed in various ways (illustration, p. 296).

[1]Pages 92–94. [2]Pages 207–208, 210, 213.

Scurvy was formerly much more common than now. In earlier times it was often epidemic among sailors on long voyages, among crusaders, among the people of besieged cities, and among all others, then as now, whose diet lacked fresh fruits and vegetables.

With this disease the joints swell and become painful; the teeth become loose; the blood capillaries are destroyed, with the result that there is internal bleeding. There are also other painful and serious conditions. Scurvy is now known to be due to a lack of vitamin C (ascorbic[3] acid).

Beriberi[4] is chiefly a disease of Oriental peoples. It is due to a lack of vitamin B_1 (thiamine[5]). Without this vitamin the nervous system is slowly rendered unable to perform its functions, the heart likewise is affected, sometimes the legs are paralyzed, and other abnormal conditions result.

Diseased conditions of the nerves are known to result from the lack of any one of several vitamins of the B group.

Pellagra[6] was formerly common in the Southern states, and it is still by no means uncommon there. It is common in many other localities of the world.

Pellagra is caused by a lack of one of the B vitamins (nicotinic[7] acid, or niacin[8]). With this disease the skin of the forearms, ankles, and backs of the hands becomes dry and inflamed. The mouth and tongue may become sore, and there are often digestive and other disturbances.

Night blindness is a less common and less serious disorder than those described in the preceding paragraphs. Nevertheless it is a factor in aviation and is always a possible cause of traffic accidents at night. It is

[3]*Ascorbic* (ȧ skôr′bĭk). [4]*Beriberi* (bĕr′ĭ bĕr′ĭ).
[5]*Thiamine* (thī′ȧ mēn). [6]*Pellagra* (pĕ lā′grȧ).
[7]*Nicotinic* (nĭk ō tĭn′ĭk). [8]*Niacin* (nī′ȧ sĭn).

Library of Congress

The land in many parts of the country is not rich enough to produce good food crops. The girl with the crutches has rickets. How does this picture relate to the discussion of hidden hungers?

caused by a deficiency of one vitamin or perhaps both vitamins of the A group.

Mineral deficiencies. A lack of minerals in a soil results in a lack of the elements composing these minerals in the fruits, vegetables, meats, dairy products, and other foods produced from that soil. Eating such foods causes hidden hungers. The nature of these hungers and their serious effects are discussed in other parts of this book.[1]

[1]Pages 92–94 and 207.

4. **Diseases caused by foods, organic dusts, and other substances: allergies.** Do you know of any kind of food that you are sure would make you sick if you ate it? Perhaps it is bread, milk, eggs, one of the common vegetables, or almost anything else that you might eat. Do you develop symptoms like those of a cold if you are around cats, dogs, chickens, rabbits, or other animals? Do you get "hay fever" or asthma[2] in the summer,

[2]*Asthma* (ăz′mȧ).

and do you sneeze frequently if you are around flowers? Do you ever "have" poison ivy, poison oak, or poison sumac[1]? Do hives or does a kind of rash appear on your skin after you have worn wool, rayon, or some other material? Does your skin blister wherever turpentine, camphor, or some other substance touches it? If you have any of these experiences, then you are probably allergic to the substances that produce the unpleasant effects.

Allergies,[2] or hypersensitizations,[3] are common. Probably most people are sensitized, or allergic, to at least a slight extent, to one or a few substances, though they may not know that they are. Some people are allergic to many substances, chiefly proteins such as those in foods, in bits of skin, fur, or feathers of animals, and in dust, mold spores, and pollens (illustration, p. 298). Fortunately, not many people are seriously affected. Those who are, however, suffer much discomfort and ill health.

The successful treatment of allergic diseases is especially difficult because (1) there is practically no limit to the number of substances that can cause them, and because, also, (2) no two people are likely to be allergic to exactly the same substances.

Doctors (allergists[4]) who specialize in such disorders use "skin tests" with considerable success to identify, or discover, what substances may be causing allergies. They make small scratches on the patient's back or forearm, and rub into each scratch a small amount of a pollen or other suspected substance; or they inject extracts, each containing one of these substances, into the skin with a hypodermic needle. The substances that they use for skin tests are the ones that most frequently cause allergies. Usually the patient reacts positively to each of the substances to which he is allergic. An inflamed, itching raised spot, or "hive," surrounded by an inflamed area, appears where the scratch was made or the needle entered.

A third type of skin test is the patch test. It is sometimes used with certain persons to identify the substances that cause rashes or blisters wherever they touch these persons' skins. A patch test is made by applying to the skin a small amount of each suspected substance; or little pieces of cloth, each dipped in a solution of a suspected substance, are fastened to the skin with adhesive tape and kept there for forty-eight hours. A substance to which the person is allergic will usually produce a rash on an uncovered patch, or a blister under the covered one.

The most certain means of securing relief from allergies is to avoid the foods, animals, or other things which the tests indicate are causing them.

Some persons can be "desensitized"—that is, they can be made less sensitive to substances to which they are allergic—by being given "shots," or inoculations,[5] by a specialist at frequent intervals throughout the year. These "shots" are hypodermic injections of extracts of the substances to which skin tests have shown that these persons are sensitized.

5. Diseases resulting from inorganic dusts, fumes, and other causes. Such diseases are many. Only a few, however, can be mentioned here. Many pages would be required to discuss even those that are common or fairly common.

In the chemical processes of many present-

[1]*Sumac* (shōō′măk). [2]*Allergy* (ăl′ẽr jĭ).
[3]*Hypersensitization* (hī pẽr sĕn sĭ tĭ zā′shŭn).
[4]*Allergist* (ăl′ẽr jĭst).

[5]*Inoculation* (ĭn ŏk ū lā′shŭn): act of inoculating. *Inoculate* (ĭn ŏk′ū lāt): to introduce disease germs, their products, antibodies, or a specific into an organism to increase its resistance to a disease (illustration, p. 192).

Hugh Spencer

Three common plants whose pollens cause allergies ("hay fever") in many people · Other plants whose pollens cause hay fever include Russian thistle, oak, Texas bluegrass, sunflower, cocklebur, sagebrush, hemp, Western water hemp, Bermuda grass, pigweed, redroot, sugar cane, corn, elm, and white birch

day industries, fumes are produced which cause more or less serious diseases. People do not need to be working in industries, however, in order to be in danger from chemical poisoning. Whenever we breathe the fumes of gasoline or of any of the cleaning fluids, we are becoming permanently poisoned to a slight extent. We take in small amounts of poisons whenever we eat vegetables and fruits that have been sprayed to kill insect pests, but probably not enough to do us harm, provided that the vegetables and fruits have been thoroughly washed (illustration, p. 299). Smokers sometimes inhale, in slight amounts, the fumes of similar poisons used to spray tobacco plants.

Dusts from some of the metal industries are more or less poisonous. Other dusts, such as those produced in wood-working, mining, lens-grinding, and stone-cutting industries, are injurious, though not poisonous. The particles pierce and irritate the lungs and other respiratory structures. Thus they make the injured person more likely to contract tuberculosis, colds, and other germ diseases.

How to combat diseases of these types is one of the most important present and future problems. The problem is made more difficult by the fact that new industries frequently give rise to new diseases. Scientists are constantly employed by various industries, by foundations, and by the government to find

ways of removing such dangers to workmen's and consumers' health.

6. Organic diseases. Organic diseases are the ones that are caused by the wearing out and the breaking down of various organs. They are among the most common of all. They include the so-called "diseases of old age." Prominent among these are diseases of the heart, kidneys, brain, and other vital organs.

7. Diseases due to flying Aviators flying at high altitudes are subject to several "air diseases": (1) "the bends" (aeroembolism[1]), caused by rapid changes of air pressure and marked by dizziness and by temporary and partial paralysis of back and legs; (2) expansion of the gases in the intestines; (3) "the chokes," or air asthma, believed to be caused by the forming of bubbles of nitrogen in the membranes of the throat; and (4) "blood-spitting" and "aviator's ear" (aero-otitis media[2]), the trapping of air in the ear as a result of changing air pressures.

Checking What You Know

BIOLOGICAL FACTS · (*Do not write in this book.*) **Pages 276–289.** **1.** With perhaps few exceptions, infectious diseases are caused by plant or animal *saprophytes.*

2. State six or more facts about bacteria.

3. There are *few* kinds of living things that are free from germ diseases.

4. Ringworm is a disease caused by a mold *parasite.*

5. The kinds of animals that cause the greatest number of human germ diseases are the *Metazoa* and *worms.*

6. Malaria is caused by a *many-celled* parasite which is introduced into the blood by the bite of a certain kind of *mosquito.*

7. Many disease germs, including those of malaria and trichinosis, require more than one __?__ in order to complete their life cycles.

8. Pork and fish should be thoroughly cooked in order to kill parasitic *worms* which may be in them and which can cause dangerous human diseases.

9. The proper disposal of human excreta and the wearing of shoes help to prevent *trichinosis.*

[1]*Aeroembolism* (ā ĕr ō ĕm′bō lĭzm).
[2]*Aero-otitis media* (ā ĕr ō ō tī′tĭs mē′dĭ ȧ).

Both these drawings illustrate good health practices. Explain

10. Two kinds of disease parasites that are believed to be neither plants nor animals are __?__ and __?__.

11. Name and explain five different ways in which infectious diseases may be contracted.

12. State and explain three different ways in which infectious diseases may be spread.

Pages 289–299. **13.** The diseases that cause the greatest number of human deaths are *infectious* diseases.

14. State six or more causes of non-infectious diseases.

15. Whether an individual grows normally depends largely on hormones made by the *adrenal* gland.

16. State seven symptoms that may indicate cancer.

17. Fresh fruits and vegetables in the diet are effective means of preventing diseases caused by a lack of *hormones*.

18. In the columns below are the names of common diseases. Under them is a numbered list which contains phrases or statements related to the diseases. Select one or more lettered items from the columns to match each numbered item. The correct matching of the first numbered item is indicated.

a. cancer	*e.* allergies	*h.* asthma
b. goiter	*f.* organic diseases	*i.* scurvy
c. diabetes		*j.* malnutrition
d. rickets	*g.* tuberculosis	*k.* typhoid

1. The thyroid gland secretes too much or too little of certain hormones. _*b*__ 1
2. Pollens and serums ____ 2
3. Abnormal growth of tissue ____ 3
4. The pancreas and insulin ____ 4
5. Vitamin lack ____ 5
6. Failure of various organs, due to old age ____ 6
7. It is usually relieved by giving the patient hormones from ductless glands of animals. ____ 7
8. Not enough energy foods and minerals ____ 8

BIOLOGICAL PRINCIPLES · **1.** All living things are subject to diseases.

2. Some diseases of plants and animals are caused by parasites; others are caused by parasite-like germs which are not certainly alive; and still other diseases have no relation to germ-like bodies.

3. Living things, by their life activities, affect the welfare of other living things.

4. All plants and animals are engaged in a constant struggle for energy.

5. Every kind of animal and plant has enemies, and only those that are able to avoid or to resist the attacks of enemies live long enough to produce offspring.

6. Each germ disease is caused by a specific parasite or parasite-like body.

7. Parasitism, like other associations of plants and animals, results from the struggle for survival.

Applying and Extending What You Know

AS SCIENTISTS WORK AND THINK · **1.** In certain parts of Europe less than a century ago, people were sometimes hanged as witches because they were believed to make other people sick by casting "spells" on them. This practice seems silly and cruel now. Yet there have been cases in the United States, in the past few years, in which somebody killed another person because he thought that person had "hexed" him, that is, had cast spells on him. Which of the scientific attitudes are related to these statements?

2. More than a hundred years ago Dr. René Laënnec[1] was treating a young woman for a serious heart disease. She was trying unsuccessfully to tell him her symptoms. As he listened, Dr. Laënnec wished that he could hear the

[1] *René Laënnec* (rē nā′ lā nĕk′).

sounds of the heart itself. He thought that they might tell him, far better than words, what the trouble was.

While the patient talked on, the physician suddenly remembered something that he had seen in the park that morning. Two boys at play were sending messages by code along the wooden plank of a seesaw. One of them would scratch a code message at one end. His friend at the other end, with his ear to the plank, could hear the message plainly, and would scratch out a reply.

The doctor reached for some sheets of paper. He rolled them into a cylinder, placed one end of it on the patient's chest, and put his ear to the other end. He could hear plainly the noises of the diseased heart!

For several years after that Dr. Laënnec experimented to invent a device with which to listen to heart noises. He made different kinds of cylinders, listened to healthy hearts, listened to diseased hearts, took notes on what he heard, and made many comparisons. Finally he made a report of his findings and gave the world his improved listening device. It was the first stethoscope,[1] the first model of the device that doctors now use every day.

What scientific attitudes and elements of scientific method are illustrated by this incident?

CONSUMER BIOLOGY · **1.** State as many reasons as you can why fruits and vegetables should always be thoroughly washed before they are either cooked or served raw.

2. Against what diseases does the adequate inspection of meat protect the consumer? Supplement what is said in this unit by getting further information from your butcher.

3. Is there any danger in eating uncooked, dried, or smoked fish? Explain.

4. In a metropolitan newspaper recently there was an account of twenty-two illnesses and one death from typhoid among the guests at a church supper. The infection was traced to a woman carrier who had helped to prepare the food. Several other outbreaks of typhoid had previously been traced to this same woman when she had prepared food. In this same city the health department had more than forty other similar carriers under constant observation. What can and should be done to protect the consumer of "ready-prepared" foods from carriers of this sort?

[1]*Stethoscope* (stĕth′ō skōp).

APPLYING YOUR KNOWLEDGE OF BIOLOGY

1. During a recent year several schools experimented with a new idea. During the winter months all the children wore gauze masks while they were in school. These masks covered only their noses and mouths. What do you think was the purpose of this experiment?

2. Make up a set of rules for the control of trichinosis.

3. A physician who treats a person who has a tapeworm makes sure that the drugs he gives the patient remove not only the body of the tapeworm, but every other part of it, even the head. Why is it important that the head be among the removed parts?

4. Why do nurses and doctors wear gauze masks and sterilized rubber gloves during a surgical operation? Why do nurses who take care of newly born infants wear masks?

5. Why is it true that wild animals rarely die of old age, but that trees often do?

6. Modern methods of preserving foods by quick freezing and by refrigeration have done much to help to prevent scurvy. Explain.

TOPICS FOR INDIVIDUAL STUDY · **1.** Using a book such as Berl ben Meÿr's *Your Germs and Mine* (Doubleday, Doran & Company, Inc.), make a detailed study of one or more common infectious diseases—for example, colds, influenza, pneumonia, tuberculosis, smallpox, diphtheria, and malaria. Try to find out (1) the cause of each disease; (2) some of its symptoms; (3) how it is spread; (4) what can be done to avoid contracting it; (5) its period of incubation; (6) whether immunity results from an attack of it.

2. What kinds of plants in your locality are known to cause hay fever? What is being done

to control these plants? What more could and should be done?

3. Make a special study of the problem of cancer control. For accurate, free information write to the Cancer Control Society in your area. Usually there is a branch of it in the capital city of each state, and in other large cities as well.

4. Medical science has made great progress in the study of diseases, expecially during the past hundred years. Yet there are still perhaps a third of the human diseases the causes of which are not yet known. Find out from doctors and text-books on health what some of these diseases are.

EXPERIMENT · Will a moist food substance, such as a raw potato, become infected with bacteria and perhaps other fungi from the air? Most bacteria are too small to be seen readily with the ordinary school microscope, but a colony of them may be grown to sufficient size to be visible without a microscope. Cut two slices of white potato about one-quarter inch thick. Put one in each of two covered Petri dishes, and place the dishes in the upper part of a double boiler which has water in the lower part. Boil the water for one hour. Why is this done? Let the boiler cool and remove the Petri dishes without lifting the covers. When the dishes have cooled, remove the cover of one of them for a few minutes, and then replace it. Do not disturb the other. Keep both potato slices in their dishes in a dark place at room temperature. After three days examine both slices. Is there any evidence on either slice of the growth of bacteria or other fungi, such as molds or mildew? You used a control (p. 570, No. 6) here. What was it? Can you plan another experiment that would serve as a check (p. 570, No. 9)?

BIOLOGY OUT OF DOORS · *Looking for evidence of diseases in green plants.* Search your neighborhood for smut, a black powdery mass, on field corn and sweet corn. In cabbage patches try to find old roots that are greatly enlarged as a result of clubroot disease. Under plum trees look for "mummified" plums, which are a sign of a fungus disease. Find peaches bearing black spots due to peach scab, or curled peach leaves resulting from peach leaf curl. On string-bean pods look for dark spots caused by a disease (called anthracnose[1]). Look for old, dead chestnut trees which have been killed by the chestnut blight, or for elm trees killed by the Dutch elm disease. Examine potatoes for spots, which may have been caused by the disease known as potato scab. Examine the leaves of crab-apple trees and currant bushes for rust spots. Keep a careful record of what you discover.

COMMUNITY APPLICATIONS OF BIOLOGY · **1. Investigating communicable diseases locally.** Find out from your city or county health officer how many cases of infectious diseases there were in your community in the past year, and how many resulted in death. Make a graph to show the figures for each disease and display it on your class bulletin board.

2. Investigating communicable diseases in your state or province. Find out from your state or provincial government how many cases of communicable diseases of various kinds there were in the past year in your state or province. Compare these figures with those of your own community. Determine the rate per 1000 population for your state or province and your community. Is your community rate better or worse than the state or provincial rate?

BIOLOGY IN THE NEWS · Watch the newspapers and news magazines for articles about various human diseases. Look for reports of epidemics of influenza, chicken pox, diphtheria, and other diseases. Report, to your class or your science club, on those diseases that you think most important. Cut out the articles and post them on the bulletin board.

[1]*Anthracnose* (ăn thrăk'nōs).

12

HUMAN CONSERVATION THROUGH EFFORTS TO MAINTAIN HEALTH

1. *How Does the Body Defend Itself against Attacks by Disease Germs?*

From the time that man first appeared on the earth, human beings have been engaged in constant battles with living enemies. Ancient men fought with the other large animals in order to eat them or to keep from being eaten by them. Primitive people warred on one another. Also, they were attacked by parasites. These included not only such organisms as fleas and lice, but also the bacteria, the Protozoa, and all the other parasites that are known as disease germs (illustration, p. 304).

Of all the enemies that attacked our ancient ancestors the disease germs were the most deadly. The early folk learned, with more or less success, how to attack or to avoid the large predatory animals. But they had no protection against disease germs. Of course they had no way of knowing or learning that such enemies exist.

For thousands of years before there were skillful doctors and effective medicines, people had to fight their own individual battles against disease germs, without any help. Even today the best doctors and the most effective medicines are merely allies. They can help the body greatly in its struggles against attacking germs, and they can do much to correct the conditions that are causing non-germ diseases. But they do not themselves win the battles. The body must do that.

DEFENSES OF THE BODY · Over a long period of time, in its constant struggles with attacking germs, the human body has developed a number of means of defense against them. If it had not, the human race would have become extinct thousands of years ago. These means of defense are of three types: (1) those that prevent germs from getting into the body or that expel them from the body; (2) those that kill or render harmless germs that have entered the body; and (3) those that make harmless the toxins,** or poisons, that invading germs produce.

The defenses that repel or expel germs. 1. *The skin.* As is stated elsewhere in this book,[1] the trunk of a tree has a protective covering of bark, composed of dead cells. The bodies of the higher animals also have a covering of dead cells. Beneath this covering, or layer, is a thin region of living cells. These two together make up the outer skin, or epidermis. Beneath the epidermis is a second, much thicker layer of skin, the dermis.[2] This is made up chiefly of fibers

[1]Page 162.
[2]*Dermis* (dûr′mĭs).

Can you think of any serious diseases, caused by parasites, that primitive man would be more likely to contract than modern man? Explain

of connective tissue, that is, tissue that binds together other tissues (illustration *A*, p. 306).

Micro-organisms, many of them dangerous germs, are always on the epidermis. The epidermis and dermis together, however, prevent most kinds of disease parasites from entering except where there is a wound or a break of some other sort entirely through the dermis. The dermis is tough, thick, and flexible. Consequently it is not easily injured. Also, oil produced by the oil glands prevents it from cracking and thus providing openings through which germs might enter.

2. *The mucous membranes.* In one sense the food that we have eaten is not really inside our bodies. It is not inside our bodies in the same sense that our bones and blood are. It is inside a tube, the alimentary canal, which extends through part of the body. The inside of this tube may therefore be regarded as part of the body surface.

The alimentary canal, the respiratory system, and some other structures are lined with mucous membrane (illustration *B*, p. 306). This membrane is joined with the dermis at the various body openings. Thus the mucous membrane and the skin together make a continuous protective covering over all the surfaces of the body which germs might readily reach.

3. *Hairs and cilia.* The coarse hairs in the nose strain out considerable dust from the air that we breathe. Thus they prevent many germs that are a part of the dust from getting into the respiratory system. The mucus that covers the mucous membrane stops some of the germs that get past the nose hairs. So also do the cilia that project from the cells of the mucous membrane lining the respiratory organs, namely, the windpipe, the bronchi, and the lungs. These cilia are constantly moving in waves somewhat like the waves in a field of high grass over which breezes are passing, one after another. These waves of the cilia cause the mucus to flow constantly toward the throat, carrying germs and other dust particles with it and thus lessening the chances of infection.

4. *Sweat and oil.* There are openings in the skin around the hairs and at the mouths of the sweat glands (illustration *A*, p. 306). The flow of the sweat and that of the oil around the hairs carries with it to the outside most of the germs that happen to get into these openings. Sometimes, however, some germs remain and cause infections, such as pimples or boils.

There are some common, silly beliefs about pimples, such as that they are a "sure sign of bad blood." In a vast majority of cases they are nothing of the sort. Most boys and girls in their teens have pimples, to some extent. The rapid development of young people, and sometimes a faulty diet, reduce the resistance of their bodies to the germs that cause pimples. Persons with pimples are likely, moreover, to pick them with their finger-nails, and thus to carry the germs to other parts of the face, where they may produce more pimples. By keeping the face always clean, much can be done to avoid pimples and also blackheads, which are pores that have become enlarged and clogged with dirt.

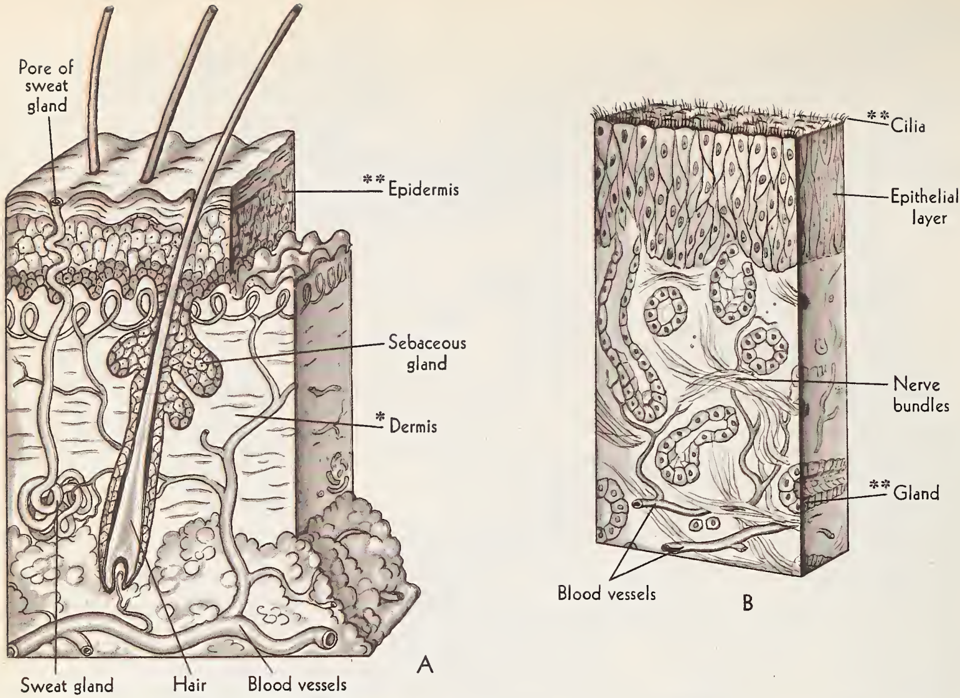
The sweat and oil on the skin are likely to cause an unpleasant body odor unless one is careful to bathe often and to change into clean underclothing frequently. One can buy harmless preparations which, when applied to the arm-pits, will, to a considerable extent, eliminate the odor of sweat (illustration below).

5. *Sneezing and coughing.* When you get some dust up your nose or something in your windpipe, you cannot help sneezing or coughing to get it out. Sneezing and coughing are also a means by which the body expels secretions containing germs when a person has a cold or a more serious disease of the respiratory system, such as pneumonia or tuberculosis.

Defenses that destroy germs or render them harmless. 1. *Cells that prey upon germs. White corpuscles.* Elsewhere in this book the

Why is bathing especially desirable after hard physical work or other strenuous exercise?

Roberts



Sections of (*A*) skin and (*B*) mucous membrane. How do germs get on our skins?

kinds of white blood corpuscles that help to prevent and to combat infections are described.[1] They move from place to place and "feed" in the same way that amebas do. They can pass from the blood stream through the walls of the blood vessels at almost any point. They wander about among all the living cells and tissues of the body. They act as predators in flowing around and digesting bacteria and other germs (illustration, p. 307). They act as scavengers in consuming dead body cells and parts of injured tissues which they happen to encounter.

Great numbers of these white corpuscles gather in and around wounds or wherever an infection has started. Many of them are killed by toxins given off by the bacteria that they engulf. The pus formed in infections is composed chiefly of lymph, dead white corpuscles and bacteria, and parts of dead tissue cells.

In attacks of certain diseases, including pneumonia, appendicitis, and tonsillitis, the number of white corpuscles in the blood increases greatly. Sometimes more than seven times the normal number are present. By "taking a blood count" of the white corpuscles in a sample of a patient's blood, a doctor is often able to detect the presence of an infection when no other symptoms indicate it.

Other preying cells. Some of the simpler invertebrates—for example, sponges[2] and hydras[3]—have certain cells in the linings of

[1]Pages 251–252.

[2]Page 215.

[3]Page 230.

their body cavities that capture and feed upon particles of organic matter that flow past them. Man and other vertebrates have cells somewhat similar to these, in the walls of their lungs, liver, and body cavities, which engulf and digest disease germs (illustration, p. 259).

2. *Tissues that surround germs.* To a limited extent the body can build walls of tissue around invading organisms. The cells of the lungs build such walls around germs of tuberculosis and perhaps of other diseases that gain entrance in spite of all the body's defenses. The lungs of most people, even of those who are healthy, would, if examined, show minute sacs, called nodules[1] or tubercles. They contain tuberculosis germs that have thus been walled up. The germs inside these tubercles remain alive, often for the rest of the person's life. So long as the walls of these tubercles remain unbroken, they are unable to cause harm. But a sudden strain from heavy physical work or violent exercise may break open the tubercles and release the germs.

Aviators sometimes develop tuberculosis as a result of flying at high altitudes. At great heights the pressure of a flier's blood is so much greater than the pressure of the air in his lungs that tubercles which were formed long before are burst open. Thus the tuberculosis bacteria are released in the flier's lungs.

3. *Fevers.* Many diseases cause fevers, or increases of body temperature several degrees above the normal temperature (98.6° F). It has long been believed that a fever is one of the unfortunate conditions which develop with these diseases (illustration, p. 309). Some recent experiments, however, indicate that fever may serve as one means of defense against the attacks of certain diseases, such as syphilis and undulant fever. One of the great medical problems now is to discover whether fevers that accompany other diseases than these are helpful or harmful.

4. *Certain secretions.* A few body fluids are to some extent germicidal (germ-killing). These include the hydrochloric acid in the stomach, saliva in the mouth, tears in the eyes, and mucus of the nose and throat.

Defenses that counteract toxins. The body is constantly being attacked by disease germs. Hence the living cells are constantly producing substances, called antibodies,[2] that help the body in overcoming diseases. Each of these substances is specific; that is, it is a defense against the attack of a particular kind of germ, but against no other. Some antibodies, the antitoxins,**[3] make harmless

[1]Page 96.

[2]*Antibody* (ăn'tĭ bŏd ĭ).
[3]*Antitoxin* (ăn tĭ tŏk'sĭn).

White blood corpuscles engulfing and consuming bacteria · Topic for Individual Study: Find out how a blood count is made. Prepare a report to be presented in your class or your science club

the toxins which the bacterial germs produce. Others (bacteriophages[1] and cytolysins[2]) dissolve bacteria. Others (agglutinins[3]) cause the bacteria to group together in masses, which the white corpuscles can more easily find and attack. Certain ones (precipitins[4]) make the germs harmless. Others still (opsonins[5]) make the bacteria more readily a prey to the white corpuscles.

A DOUBLE DEFENSE · A common belief is that, whenever there is any sort of infection, the germs themselves always spread to all parts of the system through the blood stream. This belief is in most cases false. The germs usually remain at or near the place where they have caused an infection. But their toxins are spread throughout the body by the blood stream. All the cells are able to make antitoxins. The body therefore carries on two kinds of warfare at once against a disease: (1) it destroys the germs themselves in the various ways already described, and (2) it makes the toxins harmless with the antitoxins which the cells pour into the blood.

Usually, after one recovers from a germ disease, one is immune to it for a longer or a shorter time, perhaps for life. The reason for this is that in its fight against the disease the body manufactured more antibodies than it needed to counteract the toxins. The extra antibodies will serve as a protection against future attacks of the same kind of germ.

2. How Is Human Conservation Effected through Preventive Medicine?

Two centuries ago little was known about how to prevent any disease. The best that the doctors could then do was to try to help a sick person to recover after he had become ill. Hence people lived in constant fear of "plagues" and "pestilences."

A striking example of a plague is smallpox. In the eighteenth century alone, smallpox killed nearly half as many people as make up the entire present population of the United States and Canada. In that century it was fairly rare to find an adult European who had never had the disease, and about half those who had managed to recover from it were permanently disfigured with pockmarks.

The Chinese had learned how to inoculate against smallpox much earlier. In time this knowledge was brought overland by caravan from China to Turkey. There Lady Mary Wortley Montagu, wife of the British ambassador to Turkey, learned of it and introduced it into England in 1717. However, the crude method, though generally effective, was not favorably received and was scarcely used. Hence people continued to live in constant fear of this disease until 1796. Then Edward Jenner, an English doctor, produced convincing evidence that smallpox could be prevented by vaccination.

Two other widely dreaded diseases of earlier times were bubonic plague and yellow fever (illustration, p. 310). Bubonic plague,

[1]It is believed by some bacteriologists that *bacteriophages* (băk tēr′ĭ ō fāj ĕz) are viruses that attack bacteria. A *bacteriologist* (băk tēr ĭ ŏl′ō jĭst) is a specialist in the study of bacteria.

[2]*Cytolysin* (sī tŏl′ĭ sĭn). [3]*Agglutinin* (ă gloo͞′tĭ nĭn).

[4]*Precipitin* (prē sĭp′ĭ tĭn). [5]*Opsonin* (ŏp′sō nĭn).

In earlier times it was a common practice to decide whether or not a person had fever by putting one's hand on his forehead. If his forehead "felt hot," he had fever. Why is using a fever thermometer a better method?

known as the Black Death, swept out of Asia and across Europe many times from the fifth century B.C. until about two centuries ago. Always it left countless victims in its path. During a single outbreak in the fourteenth century, lasting only three or four years, it is estimated to have killed sixty million people.

PREVENTIVE MEDICINE · [E]Smallpox, bubonic plague, yellow fever, tuberculosis, and many other infectious diseases are still greatly feared. But they are are no longer dreaded as they formerly were. Medical science has discovered and invented many ways not only of treating diseases, but also of preventing them (illustration, p. 311).

[E]Preventive medicine is constantly becoming more important and more effective. It includes (1) reducing the chances of becoming infected with disease germs; (2) detecting diseases in their early stages, when treatment is likely to be most effective; and (3) increasing the resistance of the body to infections. Important means of disease prevention are described in the rest of this section.

REDUCING THE CHANCES OF BECOMING INFECTED WITH DISEASE GERMS · **1. By getting rid of carriers of disease germs.** Until scientists discovered that flies, mosquitoes, ticks, fleas, lice, cockroaches, and other arthropods are carriers of certain disease germs, progress in fighting these diseases was slow. Since these facts have been established, many measures to control the insects that spread diseases have been put into effect. How warfare is effectively waged against some of the most widely distributed and dangerous of these insect carriers is described in the following paragraphs:

Flies. Flies develop from the egg to the adult stage in excreta, garbage, and other organic matter, but only if this organic matter is moist. Under favorable conditions they multiply at a rate that can scarcely be believed. It is estimated that it would be possible for a female fly to have more than five billion descendants during a single season if all lived and if all reproduced as soon as they became mature.

In most cities a special branch of the health department is responsible for the disposal, or getting rid, of sewage and garbage. Hence

There were nearly a hundred serious outbreaks of yellow fever in the United States from 1793 to 1901. These resulted in at least a hundred thousand deaths. **Topic for Individual Study:** The conquest of yellow fever[1]

in a sanitary city there are relatively few spots where flies can breed. On farms and in most small towns, however, the individual citizens must be responsible for eliminating breeding places of flies (illustration, p. 32).

Garbage that is unfit to be used as food for the farm animals should be buried or burned; or, if allowed to decay in order to form a compost to be used as a fertilizer, it should be thoroughly mixed with substances, such as urea and ammonium sulfate, that will kill fly larvae. Manure from the stables, barns, and fowl houses should be put into fly-tight bins until it can be spread in a thin layer over the fields, where the sun and air will dry it, or

[1]Adapted from Grace T. Hallock and C. E. Turner, *Walter Reed* (Health Heroes series). Metropolitan Life Insurance Company, New York, 1926.

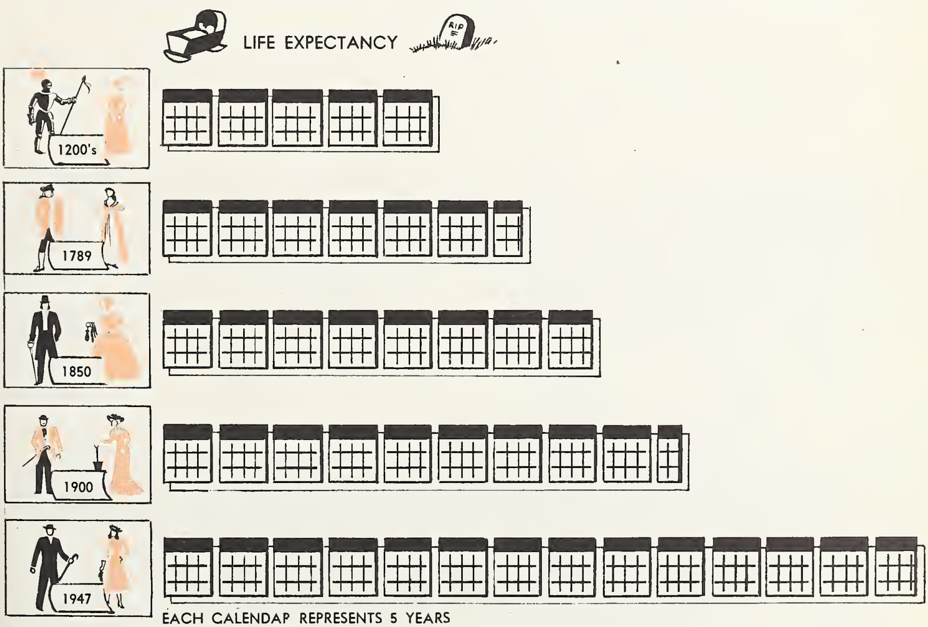
until it can be plowed or spaded into the soil. The vaults of outdoor toilets ought to be tightly built so that flies cannot get into them to lay their eggs. Even if the vaults are not fly-tight, the larvae will die if the contents are sprinkled frequently and plentifully with dust or chloride of lime. The latter will kill not only fly larvae, but also germs.

Mosquitoes. Scientists have long known that mosquitoes lay their eggs in water (illustration, p. 313). About fifty years ago they learned also that certain kinds of mosquitoes carry the germs of malaria and yellow fever. Since then they have used their knowledge of the breeding habits of mosquitoes in combating these and other mosquito-borne diseases.

Stagnant, or non-flowing, bodies of water are drained where this can readily be done. The surfaces of swamps and ponds that cannot be drained are covered with a thin film of oil. This film smothers mosquito larvae and pupae by preventing them from reaching the surface with their breathing tubes.[1] Fish known to feed on mosquito larvae are put into bodies of water which cannot be either covered with oil or drained. Reservoirs and cisterns are screened so that the female mosquitoes cannot get into them to lay their eggs. Houses are likewise screened to prevent the entrance of disease-bearing mosquitoes, as well as flies.

During the Second World War an insecticide "bomb" was invented for use by the

[1]Page 245.



The average life expectancy, or number of years that the average person may be expected to live, is longer now than at any previous time. How many reasons can you think of that might account for this fact?

Hercules Powder Company

Flies carry on their feet, bodies, and mouth parts and in their excreta the germs of many dangerous diseases. These commonly include tuberculosis, scarlet fever, and diphtheria, and sometimes tapeworm disease. The life history of the fly is a complete metamorphosis.[5] Explain

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armed forces of the Allied nations in killing mosquitoes in tents, dug-outs, and rooms. This bomb is a can of ordinary size, but built to withstand great pressure. In it are put three liquids. Two (extract of pyrethrum[1] and oil of sesame[2]) are deadly to insects, but harmless to man and other mammals. The third (Freon), a liquid used in many modern electric refrigerators, supplies great pressure. A "trigger" on the bomb releases the liquids in a mist of microscopic drops.

For two reasons this bomb spray is extremely effective as a contact poison[3]: (1) the drops are so minute that they float in the air for hours, and (2) they are small enough to enter the breathing pores (spiracles[4]) of even the smallest insects.

This bomb is finding wide use in the post-war period in killing mosquitoes, flies, and other insects in homes and in farm buildings.

Rat fleas. Rats and human beings can both be the victims of bubonic plague. People cannot, however, contract the disease directly from a plague-stricken rat. The germs are transmitted by a flea that lives on rats, in much the same way that malarial germs are transmitted by mosquitoes. The flea bites a plague-stricken rat and then serves as an intermediate (alternate) host for the plague germs. Later, if it bites a person, it infects him with the germs, just as it would infect another rat by biting it.

Port cities all over the world are carrying on vigorous campaigns to destroy the rats that might carry the fleas which transmit plague germs. These campaigns against the rat are additional to those that are being conducted against this mammal in communities everywhere because of the many kinds of serious damage that it does.

Other disease-carrying arthropods besides flies, mosquitoes, and fleas. By the means already described and others, scientists have succeeded in reducing greatly the dangers from some disease-carriers. There have remained, however, a number of arthropods that carry disease, besides flies, mosquitoes, and fleas. The control of these was not effective until DDT came into use.

DDT was given its first important trial as a destroyer of an arthropod vector[6] during the Second World War, when it was used to prevent the spread of typhus. The germs of

[1]*Pyrethrum* (pī rĕth′rŭm).
[2]*Sesame* (sĕs′ȧ mē).
[3]Pages 185–186.
[4]*Spiracle* (spī′rȧ k'l).
[5]Pages 181–182.
[6]Footnote 7, p. 280.

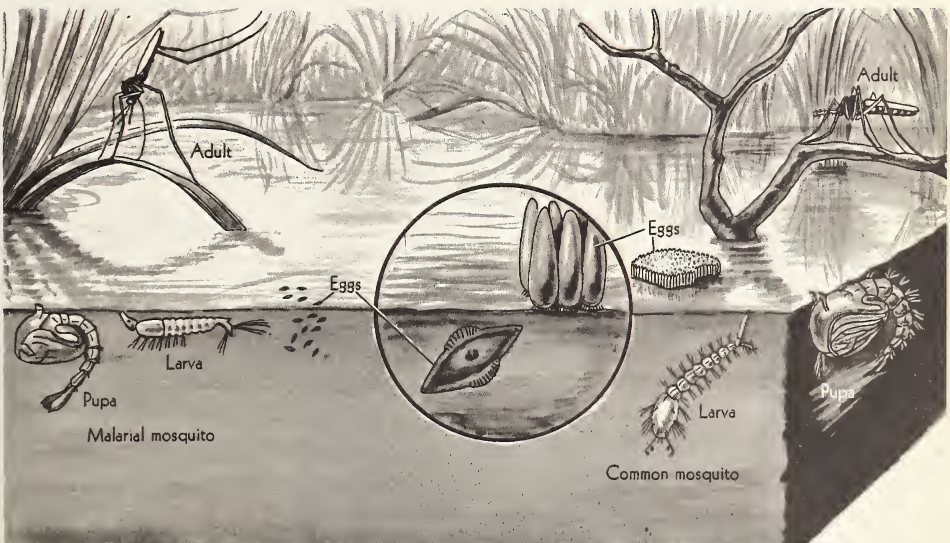
typhus are transmitted from typhus-stricken people to well people by a body louse, which our soldiers during the First World War called a "cootie."

Typhus has for generations been one of the most deadly diseases in certain countries bordering the Mediterranean Sea, because, in some localities there, people have lived under unsanitary conditions, in which lice thrive. Typhus has always tended to spread rapidly in war-time wherever conditions have prevented the people from keeping their bodies and their surroundings clean.

During the Second World War typhus threatened to sweep through northern Africa and Italy after the conquest of those countries by the Allied nations. The danger was quickly removed by DDT. DDT, in powder form, was dusted into the clothing of thousands of people in the districts where the disease had appeared. As it killed the lice, further infection was reduced to relatively few cases.

Later, DDT was used as an aid to the Allies in capturing some of the Pacific islands from the Japanese. Before our soldiers began their invasions, the swamps and jungles of these islands were sprayed from airplanes with oil containing DDT. As a result, the populations of insects that serve as vectors of malaria and other disease germs were reduced about 90 per cent. Not all, however, that resulted from this use of DDT was desirable. It was later found to have killed

The life histories of the common mosquito (*Culex*) and malarial mosquito (*Anopheles*) · State the ways in which you could readily distinguish each from the other. The life history of the yellow-fever mosquito is much like these. **Bulletin-Board Display:** Make a drawing showing the life history of the yellow-fever mosquito



most of the fish and frogs living in the areas that were sprayed.

DDT sprayed upon the walls of rooms kills every fly and mosquito that alights upon these walls during a period of about six weeks after the spraying.

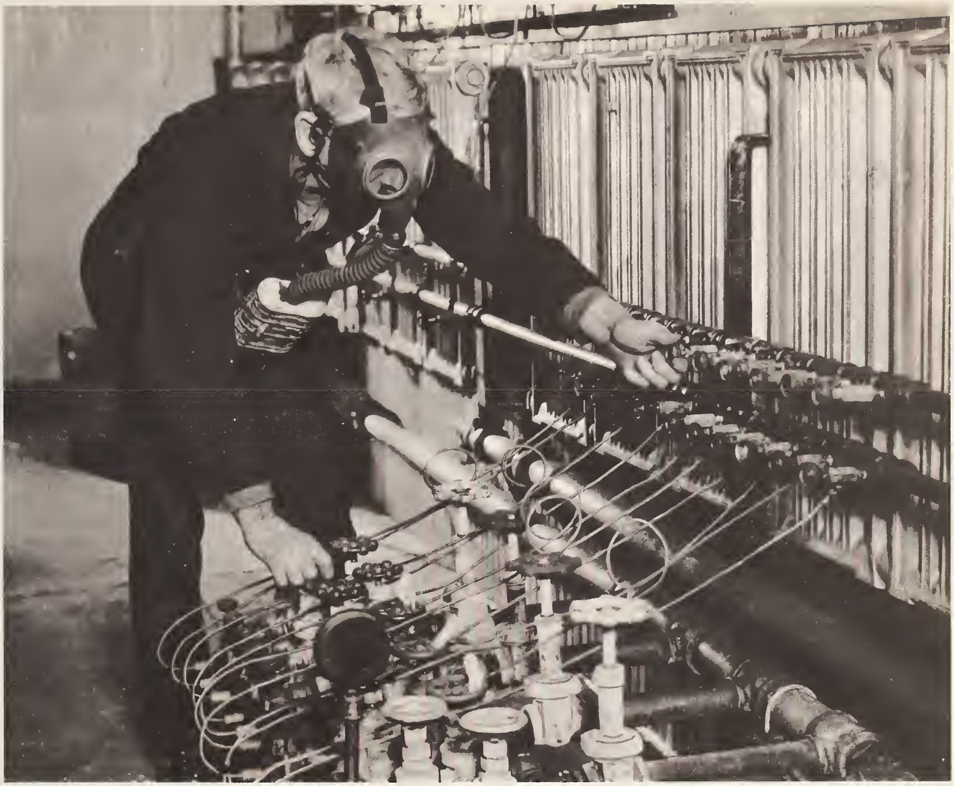
2. **By improving sanitation.** *The water supply.* In earlier times nobody hesitated to drink any water that was clear and that had no unpleasant taste or odor. People did not know then that water may look and taste pure and yet be contaminated with germs that get into it from excreta. These germs include those of typhoid, dysentery, cholera, and many other diseases. Consequently epidemics of such diseases formerly were fairly common. Occasional ones have occurred even within the past few years.

Now all cities and most good-sized towns of the United States and Canada have water systems. These supply water that is pure enough already or has been made so by killing the germs or by removing them. Germs in water are killed usually by adding chlorine to it or sometimes by spraying it into the air to expose it to oxygen and direct sunlight (illustration, p. 315). Germs are taken out of water by filtering it through sand or charcoal. Many cities use a combination of these methods to ensure a safe water supply. They maintain also sewage-disposal plants, which do much to lesson danger from the spread of germs of disease that live in body wastes.

People who secure their water directly from wells and springs should have the water tested for purity at least once a year by the

A scientist examining a sample of water from a village pool in Egypt, for eggs, larvae, or pupae of the yellow-fever (*Aëdes*) mosquito · What is the purpose of such a search? Has it any importance to people of Canada and the United States? Explain

Rockefeller Founda



Ewing Galloway

Adding chlorine to a city water supply · Why does the man wear an oxygen mask? Nearly four hundred thousand chemical and bacterial tests of the water supply are made every year by the water department of one great city (Detroit). Drinking water does not need to be absolutely free from all germs in order to be safe to drink. Explain

state or county board of health. If the water is found to be contaminated and hence "unsafe," it can be made safe by boiling it for twenty minutes.

As an important means of preventing the contamination of the water supply in the country, outdoor toilets with open vaults should be eliminated wherever possible. They should be replaced with chemical toilets or with toilets connected with septic tanks.

The food supply. Milk, cheese, butter, berries, meats, and many other foods are readily contaminated if they are prepared or sold under unsanitary conditions. There are city, county, state, and provincial boards of health which enforce laws governing the manufacture and marketing of such products.

Surroundings. When we read stories of King Arthur's court and the days of chivalry, or when we see motion pictures representing

Federal Public Housing Authority

The unsanitary dwellings shown in *A* were replaced with the attractive homes in *B*. In what ways are the conditions in *B* better than those in *A*? Why is the improvement of living conditions in the slums of great importance to the entire population of a city?

those times, we are likely to think that the old castles must have been wonderfully fine places in which to live. But if we could see them as they then were, we should not want to live in them. We should find them dark and very dirty, as judged by present-day standards for good homes. We should, moreover, find the towns and cities of those days foul and unsanitary to an extent that we can scarcely imagine.

In those times the people, even the kings and the nobles, were not dissatisfied with the lack of sanitation, as we should be now. They did not know about any better conditions. They had, of course, never heard of disease germs. They had no way of knowing that disease germs thrive in filth and darkness. Hence they could not possibly know, as we now do, that keeping streets, public buildings, and yards and houses clean is first of all a safety measure, to protect us from disease germs (illustration, p. 316).

One of the gravest and most difficult problems of this post-war period is the restoring of proper sanitation in the countries in which the war was fought.

3. By keeping clean. Probably you have heard the rather common saying "Dirt is healthy," which is intended to mean that "dirt is healthful"? The "dirt" on our hands and bodies may not in itself be harmful, but it is likely to contain many kinds of disease germs.

Keeping our bodies clean is a recent advance in civilization. The saying "It is decent to be clean" is a fairly modern one. Even now there are probably many more people in the world who do not wash their hands before eating, who do not bathe often, and who do not change into clean underclothing frequently than there are who do. We are constantly learning more reasons why it is not only "decent to be clean," but also far safer (illustration, p. 318). Such simple sanitary habits as washing our hands thoroughly before meals and keeping our hands away from our mouths may prevent our becoming infected with certain bacterial and protozoan germs and even with tapeworm.

No matter how clean we try to keep ourselves, however, there are always microorganisms on the skin. Washing and bathing reduce the numbers of these organisms and thus increase our chances of avoiding infections from dangerous ones. Soap in itself kills germs. Special new soaps, many times more effective as germ-killers than ordinary soaps, are now generally available and are finding wide use.

4. By observing quarantine. You have probably seen cards on the fronts of houses announcing that somebody within is sick with diphtheria, measles, or some other infectious disease. During house quarantine, not only the patient, but often also other people living in the house are forbidden by law to leave it, and no visitors are allowed to enter, until all danger of spreading the disease is past.

Sometimes whole cities are quarantined. For example, New Orleans was quarantined during its last great outbreak of yellow fever, many years ago. The people were warned that if they tried to leave the city they would be punished by law. In some of the neighboring towns men armed with guns constantly watched the river docks and railway stations to prevent anybody who might have left New Orleans, in spite of the quarantine, from entering their towns.

The quarantining of ships, to prevent the bringing in of infectious diseases from foreign ports, has been practiced by all nations since such quarantine was first established by the people of Venice in the twelfth century.

In the past a ship coming from a foreign port where there was known to be an outbreak of an infectious disease was kept anchored in the harbor for forty days. At present the length of a ship's quarantine may be only a few hours, but it varies with such factors as the length of the voyage and the conditions in the port or ports from which the ship sailed.

While in quarantine, the ship is not allowed to land passengers, crew, or freight. In all the principal ports of the world special hospitals are maintained for persons who arrive on ships and who are suspected of having or carrying infectious diseases. In these hospitals the persons and their clothing and other belongings are examined and disinfected.[1] Usually, also, the new arrivals are kept there until danger of carrying the diseases into port has passed.

If you have traveled through the United States by automobile, you may have been stopped at quarantine stations just inside the borders of certain states. At these stations the contents of automobiles are examined to prevent the introduction of plant diseases into a state. Usually the quarantine officers take and destroy all fruits and plants carried in the cars. Similar quarantine stations are maintained by all nations at their ports of entry to prevent the introduction of diseased plants or animals, or plant or animal pests. Inspectors carefully examine all plants, even those that remain on the ships. They dare not overlook any larvae or pupae, because these might develop into adults while the ship is in port and might then fly ashore to become pests or to spread plant diseases.

People are subject to severe punishment by law for breaking quarantine. Nevertheless many people do break it. There have been numerous instances in which such people have spread smallpox, scarlet fever, or some other dangerous disease and thus have indirectly caused many new cases and often several deaths. No good citizen would risk the safety of others in this way.

[1]*Disinfect* (dĭs ĭn fĕkt′): to kill germs or, in some cases, germ-carriers such as insects. *Disinfectant* (dĭs-ĭn fĕk′tănt): anything that kills germs, such as heat, sunlight, or a chemical. Other terms commonly used in place of *disinfectant* are *germicide* and *antiseptic* (ăn tĭ sĕp′tĭk).

A clean person is an attractive person · In earlier times skin diseases were much more common than now. How is this fact related to the third paragraph on page 317?

Westinghouse Electric and Manufacturing Company

Sorting blood donations under ultra-violet lamps • What sanitary practices besides the use of the lamps are shown here?

5. By isolating sick people. People sick with infectious diseases should if possible, be isolated, that is, kept away from those who are well. This should be done even though the patient has only a cold or some other disease that is usually not considered dangerous.

6. By maintaining ventilation. Out of doors, people rarely contract infectious diseases that are transmitted by air-borne germs, that is, those that float about in the air. Indoors, in an unventilated sick-room, one's chances of contracting such a disease are great. Therefore a sick-room should be ventilated for the purpose of clearing the air of germs, as well as for the usually more important purpose of keeping the air circulating.

The window should be open an inch or so at both top and bottom. It should be provided at the bottom with a slanting board to direct the cold currents upward toward the ceiling, or it should have a screen in front of it to protect the patient from drafts.

Air-conditioning is a modern type of ventilation. In air-conditioning dust is removed from the air, and the proper amounts of moisture and heat are added to it, or are taken out of it, before it is circulated through

homes and public buildings. When properly maintained, it is an effective means of reducing the chances of contracting colds and other infectious air-borne diseases.

7. By sterilizing the air. Recently electric lamps have been invented which kill germs by means of their ultra-violet light (illustration, p. 319). Such lamps have been used with considerable success in hospitals (especially those providing care for babies), where the air is relatively free from dust. Hospital beds are surrounded by these lamps, which destroy germs in the air and on the floor, and thus protect the baby from infection. Ultra-violet lamps, however, have not yet been perfected sufficiently to disinfect the air in public rooms.

Nearly a hundred years ago Lister,[1] a famous English surgeon, sprayed a solution of carbolic acid into the air of the hospital room in which he was about to perform a surgical operation. By doing this he hoped to prevent surgical infections by killing germs that might settle into the wounds from the air. This method was not effective. Lister did, however, make the important discovery of how to prevent surgical infections by sterilizing the operating instruments, the surgeon's hands, the bandages, and everything else that might touch the wound.

Within the last few years some experiments have been carried on, similar to those of Lister, in which various germicides have been sprayed into the air of sick-rooms to kill the germs of air-borne diseases. It is too early as yet to know how successful these experiments will prove, but the results already gained are encouraging.

One or more recently invented sprays have proved to be highly efficient germ "traps"

[1]Lived, 1827–1912.

What is the relation between this illustration and that on page 311?

Miller, from Black Star

Roberts

A strong, healthy body is perhaps the best defense against disease. Everybody can increase his resistance to disease by having recreation along with his work, by keeping cheerful, and by following other rules of mental health discussed on pages 336–344. How are this illustration and its legend related to the illustration and legend on page 237?

Where one of them has been sprayed upon walls, floors, and bedding, it has been found to catch and hold more than 97 per cent of all air-borne germs. These sprays have neither color nor odor and are harmless to people.

DETECTING DISEASES IN THEIR EARLY STAGES · **1. By frequent medical examinations.** This type of preventive medicine is well illustrated by the progress made toward controlling tuberculosis. Not many years ago tuberculosis was commonly known as the white plague. It was called a plague because it caused more deaths than any other germ disease. Modern medical science has learned how to combat it so effectively that it is no longer the dreaded disease that it was. Yet it still kills about sixty thousand people per year in the United States alone.

Tuberculosis germs can successfully attack many organs of the body, but they most frequently infect the lungs. A person may have the disease for many years before it causes symptoms that reveal it. As a result, it often reaches a dangerously advanced stage before treatment is begun. If detected in time, however, and properly treated, it can usually be cured. Therefore children who have proper medical care are now given tests, every three years or oftener, to find out whether they have contracted tuberculosis. These tests are somewhat similar to those given to detect allergies. Also, in an increasing number of schools, colleges, and industries, each individual is given a chest X ray; that is, an X-ray picture is taken of his lungs. From such an X-ray picture a physician can tell whether the person has tuberculosis of the lungs, long before the disease has developed far enough to show the typical symptoms. If the disease is shown to be present, treatment can be started at once.

ETuberculosis is only one of many diseases that can usually be cured or arrested (stopped in their development) if detected in their early stages. Hence every adult should have a thorough medical examination every year, and babies and young children oftener (illustration, p. 320). Such an examination is frequently effective in detecting, in their early stages, non-germ diseases such as cancer and heart and kidney ailments.

2. By tests. It is possible now for doctors to give tests similar to those given for detecting allergies, to discover whether the blood contains enough antibodies to prevent smallpox, typhoid fever, diphtheria, and other serious diseases. When the amount contained by the blood is found not to be sufficient, "shots" are given to build up the required immunity.

INCREASING THE BODY'S RESISTANCE TO INFECTIONS · **1. By giving inoculations.** For a few months after babies are born, they are immune to most of the common diseases. They have received from their mothers, before birth, antibodies that give them temporary protection. After the protective period has passed, however, babies are more likely to contract certain diseases than adults. From about the time that a baby is six months old until it has completed its first year of life, the modern "baby doctor" (pediatrician[1]) gives him a series of "preventive shots" to make him immune to a group of diseases which usually includes whooping cough, diphtheria, smallpox, and tetanus.

Pasteur, the famous French scientist, first discovered how to give immunity from certain diseases (anthrax[2] and rabies[3]) by means of inoculations. The kinds of substances (or vaccines) injected vary with the different

[1] *Pediatrician* (pē dĭ *à* trĭsh'ăn).
[2] *Anthrax* (ăn'thrăks).
[3] *Rabies* (rā'bĭ ēz).

diseases. Some consist of blood serum[1]** containing dead or weakened germs. Others are serums containing specific toxins which have been weakened, but which will nevertheless stimulate the body to produce antitoxins. Each of these substances, and of some other kinds, when injected into the body, stimulates the body cells to make the specific kind of antibodies needed to combat a particular disease. Thus the body increases its immunity by greatly adding to the quantities of antibodies that it would make anyway in its constant fighting against the germs.

When a child is two or three years old, the doctor gives him "booster shots"; that is, he repeats the earlier inoculations for at least whooping cough and diphtheria. Thus the child's body is stimulated to make more antibodies, which will give continued protection against these diseases.

Inoculations for various diseases are given not only to babies, but to people of all ages. Often inoculations are given after a person is known to have been exposed to an infectious disease, such as smallpox or diphtheria, but before he develops it. Thus the body cells are stimulated to produce antibodies much earlier than they would in the ordinary course of the development of the disease. As a result, the disease, when it does develop, is likely to be less serious than it would otherwise have been, and sometimes it is prevented from developing.

[1]*Serum* (sēr'ŭm): the clear yellowish liquid which remains when blood clots.

2. **By maintaining good physical and mental condition.** [E]People in poor physical health are known to become the victims of disease germs more readily than are those who are physically "fit." Having enough and a sufficient variety of good food, taking the proper amount of exercise for one's age, and getting enough rest and sleep improve the general health. Hence they increase the body's resistance to disease.

[E]Keeping the teeth and gums in good condition is an important safe-guard of health. The mouth always contains millions of bacteria because the warmth and darkness of the mouth, together with the particles of food that lodge between the teeth, provide highly favorable conditions for bacterial growth. Most of these bacteria are harmless, but some are dangerous. Antiseptic mouth-washes are

These are casts made of the same girl's teeth before and after the orthodontist treated them. What values do you think she gained from this treatment?

Dr. George R. Moore

likely to be of little or no value in preserving the teeth or in killing germs in the mouth.

ᴱThe toxins produced by the bacteria of decay or by those that successfully attack the gums pass by osmosis into the blood stream. Sometimes these poisons cause rheumatism, neuritis, and other serious diseases.

Every child should begin having regular examinations of his teeth by a dentist when he is two and a half or three years old. These examinations should be repeated every six months during the rest of his life. Thus not only can the dentist keep the teeth in good condition, but also he can detect, in their early stages, mouth infections and abnormal developments of the teeth.

The teeth of many children fail to grow in evenly (illustration *A*, p. 323). A child so affected may not be able to chew his food thoroughly. Also, his face may not develop normally. Special dentists (orthodontists[1]) are in most cases able to restore the teeth to their normal positions by means of braces and special exercises, which they prescribe (illustration *B*, p. 323).

Everybody should brush his teeth thoroughly night and morning. It is the brushing, and not the dentrifrice, that is important in cleaning the teeth. No dentifrice is of value in preserving the teeth, killing dangerous bacteria, or curing diseases of the gums.

ᴱKeeping in good mental health[2] is as important as maintaining good physical health. The state of one's mind is known to affect the functioning of the glands and other organs in such ways as to increase or decrease the resistance of one's body.

A POST-WAR PROBLEM · ᴱDuring the Second World War perhaps as many as thirty million Europeans either were taken from their homes to work for their conquerors as slaves, or fled from their homes to other lands when the invading armies approached. Most of them lived under conditions of malnutrition, great fatigue, exposure, and worry. Thus they were made a ready prey to disease germs.

The return to their homes, after the war, of infected people among these war victims raised one of the gravest problems of the post-war period. Attempts were made to meet it by sending to these regions doctors, nurses, and medical supplies, and by sending also food, clothing, and materials for constructing homes. Such measures helped the war victims to recover from the diseases they had, to build up their general physical and mental health, and thus to make them better able to resist further attacks by disease parasites. It will probably prove necessary to continue such aid for a number of years.

PUBLIC-HEALTH ACTS · Within the past few years several public-health acts have been passed by the Congress of the United States, providing large sums for combating certain diseases on a nation-wide basis. Different ones of these acts provide for programs against cancer, venereal diseases, and tuberculosis. One of them provides for the study of diseases and of ways and means of improving sanitation.

Mental health, as well as physical health, is of great concern to the law-makers. The many provisions of the National Mental Health Act of 1946 include an extensive program for the study and improvement of mental health throughout the United States. Also, this act appropriates several million dollars for the establishment of a National Institute of Mental Health.

It is to be expected that more acts will be passed in the future, in the general move to conquer physical and mental diseases.

[1]*Orthodontist* (ôr thō dŏn'tĭst). [2]Pages 336–344.

Patients and nurses in a receiving room of a hospital for Indians in Arizona · With this tribe science has taken the place of the medicine man, whose favorite treatment for all sorts of maladies was to cover the patient with mud and then throw him into the air. **Topic for Individual Study:** Primitive ways of treating diseases[1]

3. How Is Human Conservation Effected by Science in Helping Us to Recover from Diseases?

Pioneer tales relate that certain tribes of Oregon Indians had one chief remedy which they used for all cases of serious illness. Rocks were heated in a small hut on the bank of a river. The sick person entered or was carried into the hut, water was poured upon the hot rocks, and the door of the hut was closed. After the patient had sweated in the hot steam for a long time, he jumped or, if unable to walk, was thrown into the river. Often the shock of the cold water on his overheated body killed him immediately. Once, only a few members of an entire tribe survived when they used this treatment in an epidemic of smallpox (illustration above).

How foolish it seems to us now for the Indians to have used the same "cure" for every kind of serious illness that they had! This treatment, however, perhaps had a slightly scientific basis. The Indians probably

[1] Reproduced by special permission of the *Saturday Evening Post*; copyright, 1944, by the Curtis Publishing Company. From *Sagebrush Surgeon*, by Oren Arnold.

adopted it because they had tried it with certain illnesses that had happened not to be very severe, and had observed that the sick people seemed to recover more rapidly afterward. Their method of treatment, moreover, is no more foolish than the common practice today of taking "tonics," laxatives, vitamins, or large amounts of aspirin whenever one has symptoms of illness.

A doctor going forth to treat plague victims in Rome in 1656 · The leather clothing was designed to protect the doctor. The mask and wand were intended to frighten away the evil spirits which were believed to cause the plague. Were these measures to combat the disease intended as preventives or as specifics? Explain

Schoenfeld, from Three Lions

WAYS OF COMBATING DISEASE · Medical science has discovered and invented a number of effective ways of helping the body to overcome both infectious and non-infectious diseases. Some of the more important ones are discussed in this section.

1. Inoculating with antitoxins. A person may become sick with a germ disease in spite of earlier inoculations that were given to increase the quantities of antibodies which his body cells normally make. Then he must be given antitoxins and other antibodies ready-made. He is inoculated with the proper serums containing antibodies, to supplement those which his body cells have previously made and are then making under the attacks of the germs of that particular disease.

Most of these serums are secured from horses. A young, healthy horse is inoculated with a sufficient amount of the toxin produced by the disease germs, to cause its body cells to manufacture the corresponding antitoxin, but not more than the horse's body can readily counteract (make harmless). At intervals the same horse is inoculated with greater amounts of the toxin in order to increase the quantities of antitoxin in its blood. Blood is then drawn from the animal, and the clear serum containing the antitoxin is removed for use.

Sometimes a person who is allergic to horses will become seriously ill, and may even die, when inoculated with horse serum. For this reason the doctor, before injecting the serum, usually gives the patient a test for sensitization to horses. If the test is positive, —that is, if it shows that the person is allergic to horses,—he is tested for sensitization to other animals, such as goats, rabbits, or cows.

Margaret Bourke-White (A) ; E. R. Squibb and Sons (B)

Photographs of (*A*) a penicillin[1] culture and (*B*) separate mold plants (*Penicillium*) taken through a microscope · Topic for Individual Study: Other antibiotics[2] besides penicillin, such as gramicidin,[3] polymyxin,[4] chloromycetin,[5] and aureomycin[6]

He is then inoculated with a serum from an animal to which the test shows that he is not sensitized.

It is expected that serums prepared from human blood, obtained from blood donations, will soon replace animal serums for inoculations. Some serums, including those for Rocky Mountain spotted fever and sleeping sickness, are prepared from chicken embryos. The chickens are infected with the germs while developing in the shell, before hatching.

Inoculations with specific antitoxins (antivenins[7]) are now used with more success than is gained with any other treatment for people who have been bitten by poisonous snakes.

2. Giving the patient specifics. Physicians have been experimenting for centuries to find specifics. A specific is a medicine that is valuable to a marked degree in combating one particular disease or a limited group of diseases. Until the recent medical advances due to modern chemistry, however, the number of specifics has remained small.

[1]*Penicillin* (pĕn ĭ sĭl′ĭn), pp. 328–329.

[2]Such a drug as penicillin is known as an *antibiotic* (ăn tĭ bī ŏt′ĭk) from *antibiosis* (ăn tĭ bī ō′sĭs). Antibiosis is the association of two kinds of organisms whose life habits make them enemies, by which one of the two is harmed. Compare antibiosis with symbiosis (see Index) and other forms of associations.

[3]*Gramicidin* (grăm ĭ sī′dĭn).

[4]*Polymyxin* (pŏl ĭ mĭk′sĭn).

[5]*Chloromycetin* (klō rō mī′sē tĭn).

[6]*Aureomycin* (ô rē ō mī′sĭn).

[7]Page 543.

THE STORY OF PENICILLIN

A FORTUNATE CHANCE HAPPENING in 1929 led to one of the world's greatest medical discoveries. Dr. Alexander Fleming, an English scientist, was examining a bacterial culture which he had prepared for the study of some special problem. The surface of the culture everywhere was fairly white with colonies of bacteria—everywhere, that is, except in one spot. That spot was a tiny area around a speck of green. This area was covered with a clear fluid.

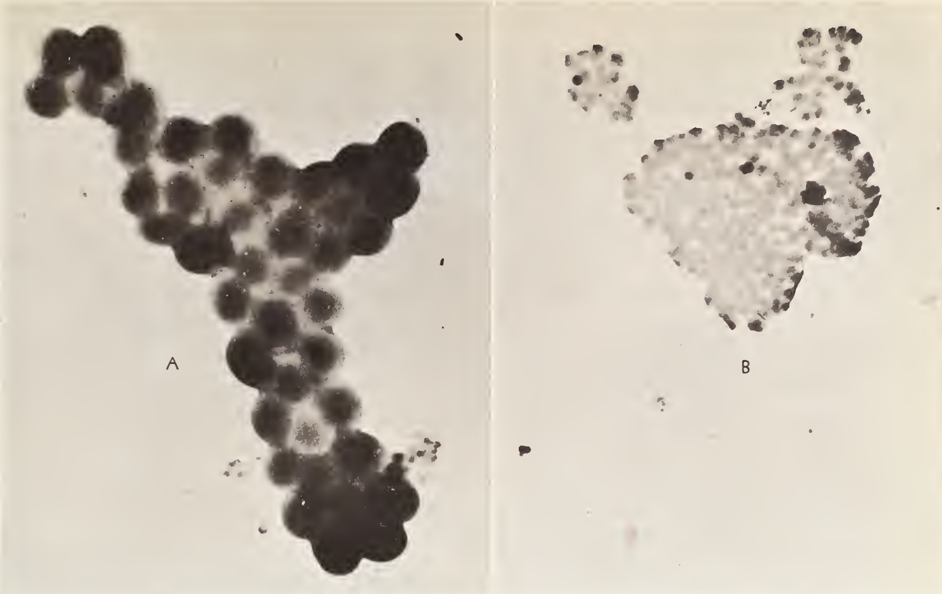
Dr. Fleming recognized the green speck to be a mold. He thought that a mold spore must have settled upon the culture from the air, and, finding the culture suitable as food, had formed a colony there among the bacteria.

The scientist studied the clear space intently. Why was that particular spot clear when the culture everywhere else was milky with bacteria? The reason must be, he inferred, that the mold was killing all the bacteria around it. In other words, in their struggle for the same food on the plate, the mold was able to destroy the bacteria. Some substance which the mold produced, Dr. Fleming further inferred, must be able to kill bacteria—at least some kinds of bacteria.

It has often happened when an important scientific discovery has been made that its importance has not been immediately realized. This happened in the case of Dr. Fleming's chance discovery. Hence no use was made of it until ten years later, when the Second World War was raging in Europe. Scientists of all the warring nations were trying, in every way they could think of, to find more effective means of preventing and curing wound infections. Dr. Howard Florey, who was working on this problem with a group of other English scientists, remembered Dr. Fleming's discovery. It occurred to him that if the kind of mold that Dr. Fleming had discovered was able to kill bacteria on a culture plate, perhaps it could destroy bacteria in wounds. That was a possibility worth investigating.

Dr. Florey and the scientists working with him began to plan and carry out a long series of experiments to find out how effective as a germ-killer the substance which the mold produced might be. After months of careful work, they succeeded in producing from the mold a tiny bit of yellow-brown powder. This was the first penicillin (named after the mold *Penicillium notatum*, from which it had been prepared). They were ready then to find out whether penicillin would kill bacteria.

They experimented first with mice. They divided fifty mice into two equal groups and made each group sick with dangerous bacteria. To the first group (the experimental group) they gave penicillin inoculations. To the second group (the control group) they gave no treatment of any sort.



Science Service

The first photographs to show the effects of penicillin. *A*, the grape-like cluster is made up of bacteria (cocci[1]) magnified nineteen thousand times by an electron microscope.[2] *B*, the same bacteria after penicillin had been introduced. Which of the elements of scientific method (p. 570) can you identify in "The Story of Penicillin"? Which of the biological principles (p. 349) are suggested or illustrated in it?

All but one mouse of the experimental group recovered, but every mouse of the control group died within less than a day. Many check experiments followed, with similar results.

In 1941 doctors were ready to test the values of penicillin with human patients. With it they were successful in curing not only wound infections, but also many other diseases for which previously no cure had been found.

Then began the difficult task of providing enough penicillin for the war needs. Laboratories in all the Allied nations began to manufacture penicillin. For the first years after the United States entered the Second World War there was scarcely enough to supply the members of the armed forces, and practically none at all for others.

The use of penicillin has already saved thousands of lives. The number of diseases that can be successfully combated with penicillin is growing as more is being learned about this "wonder drug."

[1]Page 280. [2]Page 404.

Two specifics have been known for several centuries. One is a certain compound of mercury which, until penicillin was produced, proved more useful than anything else in the treatment of syphilis. The other is quinine. Quinine is used in combating malaria. Within the past few years, however, several effective new specifics have been produced by biological chemists (biochemists[1]). These medicines include the sulfa drugs, penicillin, streptomycin,[2] and atabrine.[3]

The sulfa drugs. During the First World War an epidemic of Spanish influenza swept over the world, leaving hundreds of thousands dead in its path. This disease, in itself, is seldom fatal, but it leaves its victims so weak that they are likely to die of other diseases, chiefly pneumonia, that usually follow it. A similar epidemic threatened during the Second World War. It was prevented chiefly by the use of certain sulfa drugs.

The sulfa drugs are a closely related group of complex chemical compounds made up of the elements hydrogen, nitrogen, oxygen, sulfur, and carbon. The atoms of these elements are synthesized[4] by chemists in certain definite arrangements to form the various sulfa compounds.

The sulfa drugs and their close chemical relatives the sulfones[5] and the sulfonamides[6] already number several thousand, and new ones are constantly being synthesized. Only a few, however, have proved useful as specifics. These have been remarkably effective in combating many types of pneumonia and other bacterial diseases, some of which before were practically always fatal.

[1]*Biochemist* (bī ō kĕm′ĭst).
[2]*Streptomycin* (strĕp tō mī′sĭn).
[3]*Atabrine* (ăt′*ȧ* brĭn).
[4]Footnote, p. 154.
[5]*Sulfone* (sŭl′fōn).
[6]*Sulfonamide* (sŭl fō năm′ĭd).

During the Second World War every member of the Allied armed forces carried a supply of one of the sulfa drugs, in powdered form, to sprinkle into wounds. The prompt use of this treatment prevented infections and thus saved the lives of thousands of our wounded.

Penicillin and other products obtained from fungi. Penicillin is the best remedy known for many serious diseases caused by various kinds of the ball-shaped bacteria, or cocci (illustration, p. 281). It is effective in many of the diseases with which sulfa drugs are also effective, such as wound infections and various types of pneumonia. It is used with success, also, in some diseases which have not responded favorably to treatment with sulfa drugs.

Another drug (streptomycin) has been found effective in attacking the germs of certain diseases, including those of whooping cough, undulant fever, dysentery, and typhoid, on which penicillin and sulfa drugs have little or no effect. This drug is obtained from a soil-inhabiting plant which is neither a bacterium nor a mold, but resembles bacteria in some ways and molds in others.

Neither penicillin nor streptomycin is a germicide. Instead of killing the germs, it prevents them from growing and multiplying. Consequently the germs soon die.

There is some evidence to indicate that germs which cause diseases that are now cured with the sulfa drugs, penicillin, and streptomycin are able to build up a tolerance for these drugs. This statement means that, in combating these drugs, the germs finally become adapted so that they can survive in spite of them. A major problem of medical science, therefore, is to develop new types of these and other specifics for which the germs have not developed tolerances.

Hundreds of substances which are produced from bacteria, molds, and other fungi and which combat germs are already known. Only a few, however, are of practical use in the war against germ diseases because the rest are either too poisonous or too weak in their action.

Atabrine. At the time of the Japanese attack on Pearl Harbor, the United States had only limited supplies of quinine on hand. This drug is made from the bark of the cinchona[1] tree, which grows chiefly in the Dutch East Indies. Quinine and totaquine,[2] made also from cinchona bark, were then the only effective preventives of malaria and remedies for it.

Without enough quinine for our armed forces, there was grave danger that malaria might prove a more serious enemy than the Japanese. Botanists were sent to the South American jungles to search for groves of cinchona trees. During the course of the war several such sources of quinine and totaquine were discovered, but not enough or soon enough to have prevented disaster from malaria if atabrine had not been produced.

German chemists had synthesized atabrine as early as 1932. Later they used this drug successfully in treating thousands of cases of malaria in Europe and Africa. They sold the patented process of making atabrine to one drug-manufacturing company in the United States. But they kept part of the process secret and sold ready-made some of the substances needed to manufacture the drug.

In 1939, however, an American chemist, Dr. A. E. Sherndal, in the employ of the drug company that was manufacturing atabrine, succeeded in working out the complete process. By the time the United States had entered the Second World War, the company was manufacturing half a billion atabrine tablets per year.

Atabrine, when correctly used, has proved a more effective specific against malaria than either quinine or totaquine. The armed forces of the Allied nations were able to continue in the mosquito-infested islands of the South Pacific only by being given small preventive doses of atabrine six days a week.

Since the end of the Second World War other drugs, more effective than atabrine in the conquest of malaria, have been synthesized by chemists. These drugs include pen-

[1]*Cinchona* (sĭn kō′nȧ).
[2]*Totaquine* (tō′tȧ kwēn).

Doctors Woodward and Doering · Dr. Woodward is holding a model of the quinine molecule, magnified one hundred and fifty million times, showing its structure. The small balls represent twenty atoms of carbon, twenty-four of hydrogen, two of oxygen, and two of nitrogen. When these atoms are arranged in exactly the way shown here, they make up a molecule of quinine. For what reasons do you think this illustration was included here?

Wide World

taquine,[1] which is believed to be a positive cure for malaria.

In this post-war period a world-wide effort is being made to reduce malaria to a point where it will no longer be one of the most serious diseases. With DDT or some other improved insecticide an attempt will be made to kill mosquitoes and their larvae in swamps and jungles or wherever else they may be found.

Synthetic quinine. For almost a hundred years chemists have been trying to synthesize quinine. All attempts were unsuccessful until 1944. In that year two young American chemists, Dr. Robert Burns Woodward and Dr. William von Eggers Doering, succeeded after only fourteen months' experimenting (illustration, p. 331).

Quinine thus made chemically is far more expensive than that prepared from cinchona bark. It is likely, however, that cheaper methods of synthesizing it will be invented. The manufacture of quinine and totaquine is important in spite of the fact that atabrine and pentaquine are both more effective. The first two will be needed in fighting malaria for a considerable time in many parts of the world, until the people can be taught how to use atabrine and pentaquine safely.

3. Performing surgical operations. *Ancient surgery.* Surgery is one of the oldest of the "healing arts." The skulls of people who lived many thousands of years ago show where holes had been cut through them with pieces of stone, for the purpose, it is believed, of curing disease. It is an astonishing fact that sometimes the victims of this crude surgery recovered from the operations, as the healed spots in their skulls indicate.

Surgery of a more or less scientific nature was practiced by the ancient Egyptians. They amputated,[2] or cut off, arms and legs. They performed also some operations on eyes. The ancient Hindus practiced the setting of broken bones. They are believed, moreover, to have invented plastic surgery, which is discussed below.

For many centuries in Europe the barbers were surgeons. In the thirteenth century in England the "surgeons of the long robe," who were the real surgeons, were distinguished from the "surgeons of the short robe," who were barbers. Nevertheless barbers in England were allowed to do minor surgery until about two hundred years ago (illustration, p. 333).

Modern surgery. The great advances in surgery have resulted from great scientific advances, such as (1) the gradual growth of knowledge about the structure of the human body and about how its organs function; (2) the discovery of the circulation of the blood; (3) the invention and perfection of the microscope, the X ray, and various surgical instruments and other surgical aids; and (4) the discovery and invention of anesthetics.

Plastic surgery is a modern science by which features of the face, or in some cases other organs, such as fingers, can be replaced by the skillful grafting of skin, bone, and other tissues. New noses, new cheeks, and other features have made normal living possible to many who have lost these organs in battle or in accidents.

Skin-grafting and tissue-grafting are now widely and successfully practiced. In cases of severe burns, skin, taken usually from the thighs, is grafted upon areas where the skin has been destroyed. Bone-grafting, and lately nerve-grafting, and the grafting of certain structures of the eye have been employed with favorable results.

Surgery is used as an aid in effecting cures of an enormous number of diseases, and is the

[1] *Pentaquine* (pĕn′tȧ kwēn). [2] *Amputate* (ăm′pū tāt).

The Bettmann Archive

A barber surgeon, from the painting by Teniers[1] · What unsanitary conditions and practices, as judged by modern standards, are suggested here?

[1]*Teniers* (tĕn′yẽrz).

only effective treatment of some of the most serious ones, including appendicitis and certain cases of cancer. It is of equal importance in cases of battle wounds and of injuries suffered in accidents (illustration, p. 346).

4. Using the X ray. The chief use of the X ray in the practice of medicine is in taking pictures which show fractures of bones or diseased conditions of organs. The X ray, however, is effective also in treating certain disorders of the circulatory system and in destroying cancers and other growths.

5. Using radium. Radium is used sometimes in treating cancer and some other diseases. It is employed also in removing certain kinds of warts, moles, and other undesirable growths on the skin.

6. Raising the body temperature. Experiments have recently been made in raising the body temperature artificially to fever temperatures, even to 106° F. These experiments have been to some extent successful in cases of undulant fever, syphilis, and a few other diseases.

Radar is now being used with promising success in cases in which it is desirable to heat certain tissues or a certain organ.

7. Sterilizing wounds. Germs of tetanus and other dangerous infections can enter the body through breaks in the skin. It is therefore important to sterilize all such wounds. A good household germicide for sterilizing scratches and other small wounds is a 70 per cent solution of grain alcohol in water, by

Teaching bandaging in a Junior Red Cross chapter in Minneapolis · Science-Club Project: To organize a first-aid class in your science club so that you may learn how to apply first aid

American Red Cross

What sentence on this page is best illustrated by both these drawings?

weight. This can be prepared only by a druggist or a chemist. Serious wounds should be treated at once by a physician, who will probably dust a powdered sulfa drug into the wound and give an inoculation to prevent tetanus.

Cleanliness is especially important in the care of every wound, however small. The surrounding skin should be thoroughly washed with soap and water before an antiseptic is applied. Soap is itself a germicide. A wound should be protected with a sterile bandage (illustration, p. 334). A sterile bandage is one on which the germs have been killed by its being boiled for at least twenty minutes in water, or by other means, and which has then been protected by a wrapping so that germs cannot get on it. The bandage must be really sterile and not merely one that looks clean.

SELF-DOCTORING · Many people doctor themselves. Whenever they feel ill, they "take something." Usually what they take is a medicine which they have used before when they have had similar symptoms, or one which has been recommended to them by somebody, or one which they have seen advertised in the newspapers or have heard advertised over the radio (illustration above).

[E]Much of the doctoring that people do for themselves probably does them no direct harm. But some is dangerous. An example is the taking of a sulfa drug or other medicine which has been prescribed by a doctor for some other member of the family who may have had an entirely different disease. Another example is the taking of sleeping tablets when they have not been prescribed by a physician. Many deaths have resulted from this practice.

[E]Even when self-doctoring does not happen to injure the sick person directly, it may indirectly do him great harm by causing him to put off consulting a doctor about his symptoms until it is too late for him to be helped.

[E]One should consult a physician if symptoms of illness continue. Many diseases have similar symptoms. Only a physician is trained to discover which of several possible diseases is causing them. He knows what medicines to use for the various diseases and the amounts of them to prescribe. Also, he knows when it is best not to use medicines at all.

4. How Is Human Conservation Effected through Maintaining Good Mental Health?

When a wild animal becomes sick or is injured, its chances of recovering are likely to be few. Its body must overcome the disease or heal the injury without the help of medicines or special care. It is likely to die from lack of food, water, or other life necessities, which it cannot secure because of its handicaps. It is an easy prey to predatory enemies. If it is one of several kinds of "social" animals, such as wolves and wild dogs, that live in packs, it is likely to be set upon and killed by others of its own kind.

In the days of ancient man a sick or an injured person had little better chance of recovery than any other sick or injured mammal. Through several thousand years, however, man has been improving his knowledge and means of maintaining good physical health. It is only recently, however, that he has become scientifically interested in the improvement of mental health.

MENTAL HYGIENE, A MODERN SCIENCE · [E]There is now a rapidly increasing number of highly trained "doctors of the mind" (psychiatrists[1]), who treat mental disorders (illnesses). Such disorders are indicated by unusual and prolonged worry and anxiety, sudden marked changes in behavior, long-continued moody spells, or fixed incorrect ideas that cannot be changed by facts or reason. It is just as important for persons with such symptoms to have the immediate help of a specialist in mental diseases as it is for a person who coughs blood or has severe pains in his abdomen to have the help of a medical doctor.

The "doctors of the mind" not only are constantly improving their methods of treating mental disorders, but also are developing the science of mental hygiene. Mental hygiene is the science of maintaining and improving mental health. Like physical hygiene, therefore, mental hygiene is an important means of disease prevention.

[E]Mental disorders are common. Perfect mental health is perhaps as rare as perfect physical health. It is possible, however, for most people to maintain good mental health by observing rules of mental hygiene, just as it is possible for them to keep their physical health at a high level by following rules of physical hygiene. Important rules of mental hygiene include these:

1. Use your energy wisely. The energy which we secure chiefly from our food is truly our "working capital." Much of it, of course, is consumed in carrying on the bodily processes. Most of the rest is expended during our waking hours in carrying on three main types of activity. These types are (*a*) day-dreaming, (*b*) engaging in physical activities, and (*c*) solving problems. It is important that we learn to recognize each of these types and that we develop habits of using them in the most effective and satisfactory ways.

a. Day-dreaming. Have you ever wished that you were rich, that you had a different job, that you could travel, that you were more prominent or popular in school, or that your life were, in some other way, different from what it is? Engaging in this kind of wishing is known as day-dreaming (illustration, p. 337).

Practically everybody day-dreams more or less. A limited amount of day-dreaming is desirable. It can help us to set worthy goals

[1]*Psychiatrist* (sī kī′ *ȧ* trĭst).

for our achievement. For example, a boy who enjoys imagining himself as a prominent newspaper reporter may be influenced by this day-dream to decide to study journalism as a career. The girl who wishes that she might make important discoveries, such as those of Madame Curie, that would make her honored throughout the world may develop the ambition to become a scientist. The boy or girl who enjoys imagining himself or herself as a prosperous country dweller may be stimulated by this day-dream to become a scientific farmer or poultry-raiser.

[E]In such cases as these, day-dreaming is a valuable activity because it stimulates ambition. But we must recognize that day-dreaming will not of itself achieve any goal. Excessive day-dreaming, moreover, is likely to develop two unfortunate habits: (1) substituting day-dreaming for actually working toward our goals and (2) withdrawing or escaping from reality, that is, failing to face conditions as they really are.

With respect to the first, it is so much easier to wish to do something than to do it that we may use up all our available energy and time in merely wishing that we had accomplished our goals. With respect to the

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[E]One way to avoid engaging in too much day-dreaming is to try to develop a strong interest in the things that you must do. Such an interest is developed by (1) learning more about the work to be done; (2) doing the work so well that you can take a pride in it; or (3) trying to find ways to improve it. Day-dreaming and wishful thinking are often called escapes from reality. Can you explain this statement?

Encyclopædia Britannica Films, Inc.

second, we may try to avoid responsibilities and difficult situations by withdrawing our thoughts into a make-believe world which we construct from our fancies and in which we can imagine ourselves as being always happy and successful. We must therefore recognize that not much energy and time may profitably be invested in day-dreaming, and that spending excessive portions of them in this form of activity is dangerous to mental health.

"Wishful thinking" is closely related to day-dreaming. When we indulge in wishful thinking, we allow ourselves to believe that what we hope will happen is going to happen. For example, a boy may feel sure that because he wants and badly needs a job during vacation, he will have a good job then. A girl may expect that because she would like to be a good student, she will become one. The danger in wishful thinking lies in substituting the wish for the effort which is necessary to make the wish come true.

b. Engaging in physical activities. [E]Everybody must use part of his energy in physical activities (illustration below). We cannot do our work without moving about. Also, we need sufficient exercise to keep us in good

A nature trail inside the limits of a great city · Community Application of Biology:
What nature trails are within hiking distance of your home? "Big muscle" activities, such as hiking and strenuous games, are especially valuable to young people as means of maintaining good physical and mental health

New York City Park Department

physical condition. But we must not spend too great a portion of our energy and time in physical activities. If we do, we shall not have enough remaining so that we can study, plan, or do other important mental work.

c. Solving problems. Early man's needs were simple. Consequently he had relatively few problems to solve. These problems mainly arose in connection with obtaining food, shelter, and other life necessities, and with avoiding or fighting enemies, chiefly the larger predatory animals. Primitive man was able to solve most of these problems through direct physical activity. In modern society, however, our needs are many and complex. We can provide for relatively few of them by mere physical activity. Success in the modern world can be gained only through problem-solving.

Everybody is constantly meeting problems (illustration, p. 340). These range from simple ones, such as "Shall I take the bus or walk today?" "Shall I listen to the radio for a few minutes?" and "Shall I cross the street at this corner or the next?" to complex ones, such as "What shall I make my life-work?" "How can I buy all the things I need with the money that I have?" and "How can I improve my work at school?"

[E]Problem-solving and day-dreaming are alike in the beginning. Each starts with sensing a problem. But the day-dreamer substitutes imagining a solution for bringing one about. In contrast, the problem-solver feels that he must solve his problem, and not try to escape from it. Hence he plans the steps by which he will try to solve it. Then he immediately begins to carry out these plans.

[E]In the highest type of problem-solving, a person constantly studies his work in order to try to think of new and better ways of doing it. When he has decided what promises to be a better way, he puts it into practice in order to find out whether it actually is better. Thus he uses, or employs, initiative. Initiative is "drive," or "self-starting" and "self-continuing."

All human progress has resulted from employing initiative. During the Second World War workers in war industries were encouraged with money prizes to employ initiative in inventing and trying out better ways of doing their jobs. They made thousands of suggestions, many of which were carried out and contributed substantially to winning the war.

We can have enough energy and time for problem-solving only if we reduce the proportions that we expend in day-dreaming and in physical activity. Problem-solving, especially problem-solving in which we must use initiative, is as important in maintaining a sound, active mind as physical exercise of the right kinds is for maintaining a strong, healthy body.

2. Finish what you start. Do you know somebody who seems to have good ideas about how things should be done, but who never gets them done? Perhaps he fails because he spends so much of his energy and time in day-dreaming and physical activity that he has not enough left to carry out his plans. Or perhaps he wastes his time and energy by failing to stick to whatever he starts long enough to finish it. Instead, he may begin some task, work at it a while, and then think of something else that needs to be done. Instead of delaying work on the second task until he has completed the first, he stops work on the first and begins on the second. Before completing the second task he may drop it in order to start on still another.

Such a person is likely to accomplish nothing. Having failed, he is likely both to invent excuses for his failure to make progress and to escape from his feeling of not being

What problem-solving do these pictures suggest? Are these relatively simple or complex problems? Can you suggest other problems?

adequate (equal to the task) by indulging in day-dreaming. One can form the habit of not finishing tasks as easily as one can establish the habit of finishing them.[1]

3. Define your goals. Defining a goal which you hope to reach involves analyzing it so that you can plan the various steps that you must take to reach it. For example, a high-school student decided that he wanted to become a biologist. He had then to decide what branch of biology he would like best to study. He decided upon ecology.[2] Next he had to decide where he could best study this field. He consulted the catalogues of various colleges and chose the one which he thought would offer the best work in ecology. Then

[1]Page 413.

[2]Footnote 9, p. 7.

he found what courses he would need to complete in high school in order to be admitted to this college. He began at once to take these courses.

Thus the student had defined his goal so that he knew not only what he wanted to achieve, but also how to achieve it. He had analyzed the large objective, to become a biologist, into smaller ones that he could accomplish one by one. If he had not got clearly in his mind the steps that would lead him to his goal, he might have used up his time and energy in day-dreaming about becoming a biologist.

Many people need to define their large objectives, as this student did. They know in general what they want to accomplish, but they do not analyze their goals so that they know what steps they must take to achieve them. Not knowing where and how to start and to proceed, they become worried and discouraged. They may then try to escape from reality by indulging in day-dreaming and wishful thinking. Even if they do not, they are almost certain to experience frustration, that is, a sense of defeat, failure, and disappointment, which is harmful to their mental health.

4. Control your wants. Sometimes one hears the statement that anybody can achieve any ambition he has, provided that his ambition is strong enough and provided also that he is willing to work hard enough to achieve it. This is not true. Nobody can be successful in everything that he may want to do or may attempt to do. No two people are alike, and it would be ridiculous to expect them to have equal amounts of the same abilities. There are many people who could never become successful surgeons, lawyers, or other professional persons, no matter how strongly they might wish to or how hard they might try.

You may have a strong ambition to become a "movie" star or a big-league ballplayer, without possessing the necessary ability to become one. But you can find worth-while things that you can do well, or at least well enough so that you can feel successful. Perhaps you may find that you have a talent for sewing or cooking, or that you can work with tools as well as any of your friends, or better.

Each of us needs to find out both what he can and what he cannot do successfully. He must then control his desires so that he can be satisfied with doing as well as he can the things that he is capable of doing, and also so that he will not feel frustrated over not being able to do what he would like to do.

Nobody ever has everything he wants. If a person wants something that he cannot possibly get, he should accept the fact that he cannot have it and put it out of his mind. He should try to find attractive and satisfactory features in the things that he can have. His energy and time can then be used in achieving a reasonable number of desires that he can attain, instead of in day-dreaming about things that he cannot have.

5. Face your problems squarely. Everybody encounters difficult and unpleasant situations. Whenever you encounter one, face it and do the best you can to meet it. If you try to avoid it, you are not likely to succeed in doing so. Furthermore, if, in similar situations later, you try to escape from problems instead of trying to solve them, you may form the habit of "dodging the issue." The energy that you would waste in trying to get away from a problem could be used to much better purpose in trying to meet it as well as you can. Much more important is the fact that your knowing that you have met a bad situation as best you could will give you self-respect and confidence, which will

make it easier for you to deal with future unpleasant problems.

6. Avoid feeling too important. Many people are completely self-centered. They magnify the importance of everything that affects them. Thus they fail to see either their successes or their failures in true proportion. They indulge in self-pity. They make themselves miserable by fearing that others are laughing at them or by looking for offense where none is intended. In these and other ways they think too much about themselves.

Such a person needs to develop a healthy interest in what other people are doing and thinking (illustration, p. 343). He needs to try to find ways of helping others. Active membership in such an organization as the Boy Scouts, the Girl Scouts, or the Junior Red Cross provides an excellent way to avoid becoming a boy or a girl of this type.

Good ways for a person to avoid taking himself too seriously include these: Give others credit for their special abilities and for what they accomplish. Give their ideas and achievements the same consideration that you would want them to give yours. If another person receives an honor, even though it is one that you hoped to receive yourself, try not to let yourself feel frustrated. Do your best to enjoy the other's success with him, instead of envying him for having achieved it.

Training yourself to follow such rules is not easy. But it is no harder to form right mental habits than it is to form other difficult habits.

7. Look for the humor in life. A sense of humor is one of the best safe-guards of mental health. Learn to laugh "when the laugh is on you." Try to see the funny side of the experiences that you have. Release your energy in a difficult situation, whenever you can, by substituting a hearty laugh for anger or indignation. Situations whose importance has been magnified are likely to assume their true proportions if we can see the humor in them.

8. Learn to control your emotions. Violent anger or other emotional outbreaks use up great amounts of energy in a wholly undesirable way. One can form the habit of controlling one's emotions. Also, one can sometimes direct an emotional reaction into a useful channel by making it the stimulus to working for some worth-while cause. As an example, one's anger over seeing animals ill treated could cause one to become an active member of the Society for the Prevention of Cruelty to Animals. Your becoming indignant over the living conditions that exist in the poorer sections of your town can serve as the drive which makes you join with others in trying to improve these conditions.

9. Change your activity. A fairly frequent change of activity is necessary in maintaining mental health. You are not so likely to become exhausted from working too hard as you are from engaging in the same activity for too long a period without a break. The wise old saying "Variety is the spice of life" has a direct relation to mental hygiene.

10. Balance your work and play. The life of a well-balanced person includes both work and play. "Work hard and play hard" is good advice. When you have work to do, keep at it steadily and do it as well as you can, whether you like the task or not. Then, when it comes time for recreation, get as much pleasure out of that as you can.

Everybody needs a hobby, that is, something that he does for no reason except that he likes to do it (illustration, p. 13). Having a hobby makes life interesting because it gives one something to look forward to after the work that must be done has been completed. A hobby, such as making a collection, making soap carvings, or making and repair-

Garden Department, Cleveland Public Schools

Learn to work well with others. How is this picture related to rule 6?

Not everybody can "make the team." How do this illustration and its legend apply to paragraph number 4 on page 341?

Lambert

ing things in a basement workshop,—in short, any leisure-time activity that a person finds interesting is "good for his mental health." It provides a complete change of activity. Leisure time spent on a hobby ensures true *re*-creation. Such an investment of leisure time will enable you to do your work better (illustration below).

MENTAL HEALTH IN THE POST-WAR WORLD · Probably the effects of the Second World War upon mental health are as serious as its effects upon physical health. Mental disorders resulting from the strains of constant danger, fear, dread, not enough rest, lack of security, and all the other terrible conditions that accompany war are certain to be far more numerous and widespread than ever before in human history.

No post-war problem is likely to be more serious and difficult than that of restoring the impaired (injured) mental health resulting from the war. In the countries in or near which the war was fought, many conditions which cause serious mental disorders will remain during the long period of restoring the shattered populations and their ruined countries to normal living.

[E]Have a hobby. A hobby improves mental health because (1) it provides a complete change of activity ; (2) it enables you to forget yourself for the time being; and (3) it takes your mind for the time being completely off your serious problems. How many hobbies which relate to biology can you name in two minutes?

5. How Is Human Conservation Effected through Reducing the Numbers of Accidents?

Of all the places where you might be, in which one do you think you would be in the greatest danger of being injured or killed? If you base your answer upon what has happened in recent years, you will say, "At home," because most accidents have occurred around home[1] (illustration, p. 346).

During the period of slightly more than two years from December 8, 1941, the date on which the United States entered the Second World War, to January 1, 1944, nearly two hundred thousand people were killed and about eighteen and one-half million were injured by accidents in the United States (illustrations, pp. 348 and 350). During this same period about two hundred and forty thousand Americans were killed or else wounded on all the various war fronts.

In the United States the numbers of people who have suffered accidents have varied from year to year by only a few per cent. In any recent year about a hundred thousand people were killed and between nine and ten million were injured in accidents of various kinds. Of these injured people, probably more than three hundred thousand suffered permanent disabilities. This statement means that they lost an arm or a leg or some other member of the body, or that they suffered an injury to the brain or the eye or some other organ, which either prevented their working again or prevented their ever again doing certain kinds of work.

In one recent year, during which the total number of accidents was somewhat below the yearly average, the cost of the accidents in money amounted to about five billion dollars. There is no way of estimating or imagining the pain these accidents caused or the other kinds of harm and distress that resulted from them.

[E]Most accidents result from carelessness or from a lack of careful planning to prevent them. Therefore they could be prevented.[2]

Checking What You Know

BIOLOGICAL FACTS · You should review from time to time the explanation of these types of tests in "This Book and You," p. xiv. (*Do not write in this book.*)

Pages 303–308. 1. Name three types of defenses of the body against disease germs.

2. The two layers of skin, namely, the --?-- and the --?--, together, if unbroken, prevent the entrance of most disease germs into the body.

3. Many germs that enter the nose as part of the dust are stopped by the *nose hairs*, by the mucus on the mucous membrane, and by the cilia of the *epidermis*.

4. Some germs are swept out of the lungs and bronchi by the continuous wave action of the --?-- covering.

5. Pimples and boils are caused by *disease germs*.

6. State four ways in which the body destroys germs or makes them harmless.

7. State five ways in which the various kinds of antibodies help the body in overcoming the attacks of disease germs.

[1]The facts stated in this section and shown in most of the illustrations were taken from publications of the National Safety Council, Chicago, Illinois.

[2]Consult the Index for references to first aid.

Common causes of accidents in the order of the frequency with which they occur · **Science-Club Project:** Ask your teacher to secure from the National Safety Council, Chicago, Illinois, the latest bulletins on safety. Make a series of drawings similar in style to these and to those on page 348. Consult the Index for materials on first aid in other parts of the book

Pages 308–324. 8. State five or more means of preventing disease.

9. If a rat that has bubonic plague is bitten by a certain kind of *tick*, and that *tick* then bites a person, the person is likely to become sick with the plague.

10. *Typhus* is spread from person to person by body lice.

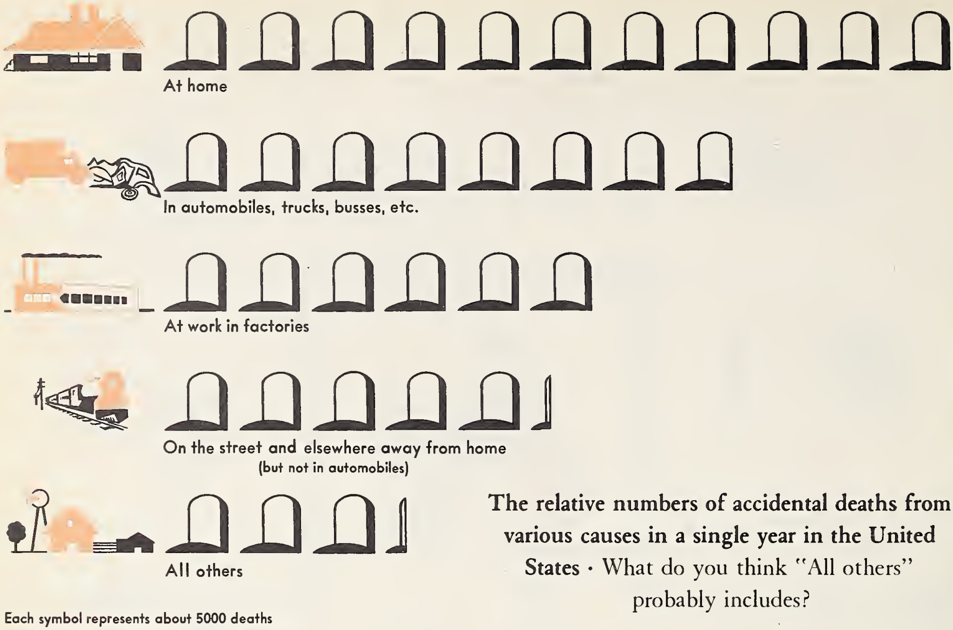
11. Disease germs in drinking water are killed by direct sunlight, by *nitrogen* in the air, and by the addition of *iodine* to the water.

12. State three methods of reducing the numbers of flies.

13. Houses in which people are sick with infectious diseases are often *isolated*.

14. Having a thorough medical examination

This is a "Cabot cross," showing how one may keep one's life activities in proper balance. Can you make up one or more questions about this diagram, such as this: "How would the 'cross' look if one had too little recreation and too much work?"?



The relative numbers of accidental deaths from various causes in a single year in the United States · What do you think "All others" probably includes?

once a year or oftener is a means of detecting in their early stages (1) only germ diseases; (2) only non-germ diseases; (3) both germ and non-germ diseases; (5) only tuberculosis; (4) only children's diseases.

15. Having inoculations to increase the body's resistance to many serious diseases is important for people of *all* ages, but is more important for *old people* than for others.

16. The numbers of living disease germs that float about in the air can be greatly reduced by means of __?__ rays.

Pages 325–335. **17.** State five means of helping sick people to become well.

18. Inoculations introduce *toxins* into the body which not only prevent people from contracting certain germ diseases, but also help people who have contracted such diseases to recover from them.

19. An important specific which is prepared from a certain type of mold is (1) streptomycin; (2) sulfanilamide; (3) quinine; (4) totaquine; (5) atabrine; (6) gramicidin; (7) pentaquine.

20. Sulfa drugs are useful for treating *all* infectious diseases.

21. *Streptomycin* and *atabrine* are useful in treating diseases because they prevent reproduction of the germs.

22. Three steps necessary in treating small cuts and scratches are (1) to wash the surrounding skin thoroughly with soap and water; (2) to apply *an antitoxin* to the wound; (3) to cover the wound with a *clean-looking* bandage.

Pages 336–344. **23.** Perfect mental health is *much more* common than perfect physical health.

24. State at least eight rules to follow in order to maintain good mental health. Give an illustration of each.

25. Our ambitions are achieved by hard work, not by __?__.

26. State three ways in which having a hobby improves mental health.

Page 345. **27.** The greatest number of accidents happen to people (1) at home; (2) in automobiles; (3) on the street; (4) in factories; (5) in traveling; (6) on farms.

28. What are the five most common causes of accidents?

29. Most accidents occur because people are *careless* and because they do not *plan* to avoid them.

ON UNDERSTANDING BIOLOGICAL PRINCIPLES · Read again the instructions on page 37.

1. Every living thing has enemies.

2. Living things affect the environment, and the environment affects living things.

3. Some living things live their entire lives as parasites upon or within other living things.

4. Some parasites require more than one host in order to complete their life cycles.

5. Many micro-organisms are killed by direct sunlight.

6. The bodies of organisms have various natural defenses against attacks by micro-organisms.

BIOLOGICAL TERMS

**antibody **antitoxin **toxin

Applying and Extending What You Know

AS SCIENTISTS WORK AND THINK · **1.** Whenever a new means of combating diseases has been invented, there have always been some people who have opposed it. To illustrate, when Jenner announced his method of preventing smallpox, many people refused to be vaccinated and gave a variety of reasons for refusing. Probably the most fantastic was the fear that if they should be vaccinated, cows' heads might grow out of any parts of their bodies because the vaccine was secured from cows. Even today, as has been said, some people try to escape from quarantine. Others oppose being inoculated as a means of preventing disease or of helping the body to overcome disease. Others insist on going about among people when they have colds, influenza, or other communicable diseases which they know are likely to spread by infecting others.

Which of the scientific attitudes do such people lack?

2. Which scientific attitudes do people lack who do self-doctoring?

3. Can you invent an experiment such as a doctor might perform in order to determine whether a person is sensitized to horse serums. Use elements of scientific method from the list on page 570.

CONSUMER BIOLOGY · **1.** What dangers to the consumer need to be guarded against in the use of DDT and other insecticides?

2. Why is it important to eat restaurant meals only in restaurants that are regularly inspected by the board of health?

3. Make a list of the drugs or medicines that are in your family medicine closet. How many are patent medicines? How many are labeled in such a way that one would not know for what diseases they were intended to be used?

4. How might self-doctoring prove expensive, as well as dangerous?

APPLYING YOUR KNOWLEDGE OF BIOLOGY · **1.** Explain why the human species still exists, although there were no scientists or physicians for many thousands of years in its history.

2. From your own experience try to answer this question: Does one obtain permanent immunity as a result of having a case of the common cold? If not, about how long does your immunity last?

3. Although mosquitoes breed only in water, they are often numerous enough to be pests in large cities. Where do they breed in these cities?

4. Is it likely that house-flies and other insects will become extinct as a result of the use of DDT sprays and other insecticides? What are the reasons for your answer?

5. Carolus Linnaeus, the Swedish botanist, once said that a fly can eat up a dead horse faster than can a lion. Can you explain this statement?

6. Which do you think is of greater importance, finding out how to treat diseases or finding out how to prevent them? Why do you think so?

7. Explain in your own words how mental health is important to you.

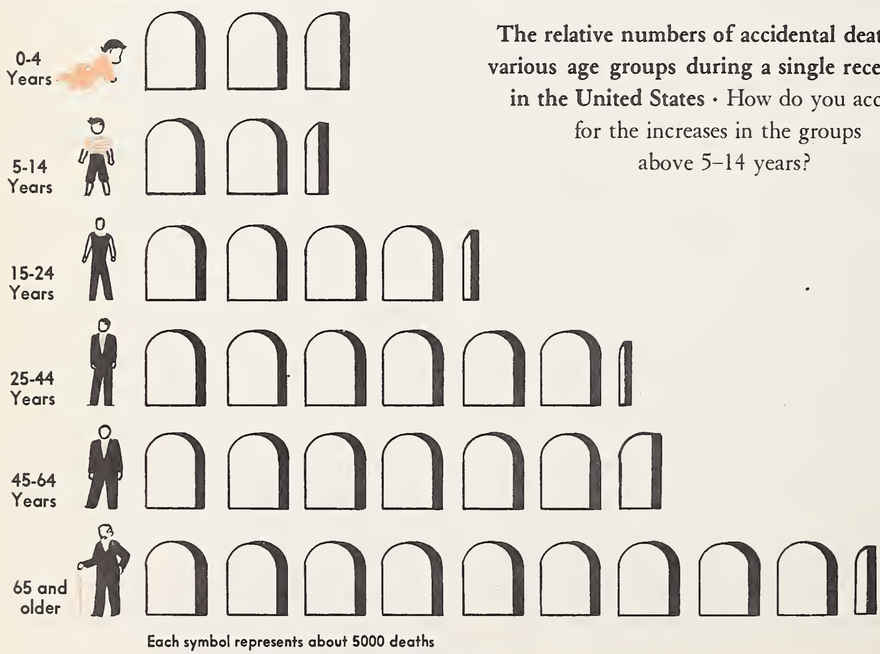
TOPICS FOR INDIVIDUAL STUDY · 1. In an encyclopedia or a history of science look up the lives of Edward Jenner, Louis Pasteur, Joseph Lister, Robert Koch, Edward L. Trudeau, and Walter Reed. Find out what they did that was of importance in helping us to understand and control diseases. In each case identify in their work as many of the elements of scientific method as you can.

COMMUNITY APPLICATIONS OF BIOLOGY · **1. Studying health regulations.** From your local board of health obtain a copy of the health regulations of your community. Find out what the regulations are concerning the reporting of infectious diseases, establishing quarantine, making school children immune to certain diseases, etc.

2. Becoming informed about the board of health. Learn who the members of your local board of health are, bow they are chosen, what their duties are, when they hold their meetings, and other similar facts. If possible, make plans to have the class attend one of the meetings.

3. Becoming informed about a public clinic. If you live in a city which has a public clinic, arrange to have the class visit it to see what is being done there.

4. Studying a food-processing plant. Arrange to visit a dairy or a food-canning plant. Study the precautions taken to keep the product clean and as free as possible of disease germs.



The relative numbers of accidental deaths for various age groups during a single recent year in the United States · How do you account for the increases in the groups above 5–14 years?

5. Studying local water purification. Arrange a trip for your class to the local water-purification plant to learn how the water is purified and how it is tested for freedom from disease germs.

6. Becoming informed about rubbish and garbage disposal. Find out what is done with the rubbish and garbage of your town. Try to determine whether the method of disposal is a sanitary one.

GROUP INVESTIGATIONS · **1. To make a survey of the infectious diseases which the members of your class have had.** Ask each member to make out a list of the infectious diseases which he has had and hand it to your teacher. Elect a committee to combine these lists into one so that it will show all the different diseases and the number of cases of each. The chairman of the committee, in making his report to the class, should tell what have been the commonest diseases within the group, what the least common, and how many cases of preventable diseases are in the list.

2. To make a survey of immunization. Find out from each member of the class whether he has been immunized against diphtheria, smallpox, tetanus, whooping cough, or other diseases. Use a method similar to that just described in combining the facts and in reporting them.

3. To study the extent to which illness is a cause of absence from school. For a period of twenty school days obtain from the principal's office, or from the person in charge of attendance, information regarding the numbers and the causes of absences. Find out for each day what proportion of the absences was due to illnesses and which kind of illness was the most common cause of these absences. Present the findings in a class discussion, in your science club, or in the school assembly.

BULLETIN-BOARD DISPLAYS · 1. Make posters or draw cartoons illustrating rules for maintaining good health.

2. Make posters showing the various animals which spread human diseases. On each poster state which disease or diseases each animal spreads.

PANEL DISCUSSIONS[1] · **1. Topic:** The improvement of the health of the people of our nation.

The panel members may prepare talks on such aspects of this problem as (1) Are the people of our nation in the best health that we can reasonably expect, or can the general health be improved? (2) What are some of the unsolved health problems which medical scientists must solve? (3) How can we make medical care available to all persons? (4) What can the schools do to improve the health of the people? (5) How can the nations of the world co-operate to secure and maintain better health for people everywhere?

After the talks by the speakers the class should join in a general discussion of the topic.

2. Topic: The citizens of a town or city should be taxed to pay for garbage collection.

3. Topic: Constructing a set of rules which promote good citizenship through preventing the spread of disease.

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[1]Page 116.

UNIT SIX

BEHAVIORS OF LIVING THINGS

What are the kinds of behavior, and how are they related to survival?

What structures are involved in behavior, and how do they function?

How is learning brought about?

American Museum of Natural History

To which of the principles on page 372 are this picture and the account of the fight between the mongoose and the cobra in the text related?

13

THE NATURE OF BEHAVIOR

1. What Are the Kinds of Behavior?

Have you read the story of Rikki-tikki-tavi in Kipling's *Jungle Book*? "Rikki" is a mongoose, a weasel-like, gray animal with a body about sixteen inches long. It lives in India, where it is considered valuable because it is an enemy of the dreaded cobra and other poisonous snakes. Cobras alone kill several thousand people in India every year.

Whenever a mongoose and a cobra meet, there is always a fight to the death (illustration, p. 354). Strangely enough, the mongoose is nearly always the victor, even though the snake may be a twelve-foot king cobra. The mongoose starts the fight by advancing toward its dangerous enemy. The cobra raises its head, spreads its hood, and weaves back and forth, watchfully facing its smaller foe. The mongoose, with its eyes constantly on the snake, cautiously moves around and around it, getting closer and closer. The cobra turns, too, trying always to keep facing its enemy. Suddenly, when just the right opportunity offers, the mongoose darts in and nips the snake in the tail. The cobra strikes, but, quick as the snake is, the mongoose is quicker, and leaps back to safety.

The mongoose then begins a series of sudden attacks, first from one direction and then from another. Each time it darts in, it nips the cobra and the latter strikes savagely at it. But it dodges each strike.

Soon the cobra begins to tire. It strikes less and less savagely and finally becomes too weary to strike at all, even when nipped. Then the mongoose is ready for the kill.

Quickly it circles, bites the reptile hard in the tail, and crouches, waiting. As the tired cobra turns, too slowly, to face its enemy again, it exposes the back of its neck to attack. Instantly, then, the mongoose leaps and seizes the snake's neck below the head, and the two roll and thrash around on the ground. But the mongoose does not release its hold and soon severs the cobra's spinal cord. Then the battle is over, and the victor makes a meal off its dead foe.

STIMULI, RESPONSES, AND BEHAVIOR · In the struggle just described, the first glimpse that each animal had of the other caused it to get ready to fight. The sight of its foe was a stimulus.**[1] The resulting preparation for battle was the response,** or reaction, to the stimulus.

You will note examples of stimuli and responses whenever you observe living things. A dog responds to the stimulus furnished by the odor or the sight of a rabbit by chasing the rabbit. The rabbit responds to the stimulus given by the sight of the rapidly approaching dog by running away. When you receive the stimulus given by the sight of a friend on

[1] *Stimulus* (stĭm'ū lŭs); plural, *stimuli* (stĭm'ū lī): any condition or situation in the surroundings that causes or arouses any sort of action in an animal or a plant. Whatever the stimulus causes the organism to do is its *response* to the stimulus.

the street, you make the response of speaking or waving a greeting.

All the responses, together, that a living thing makes to stimuli make up its behavior.[1] No two living things have the same behaviors, but all have behaviors. Most, but not all, behaviors involve movement that can be observed. Movement in itself, however, is not necessarily behavior. Non-living things move. Clouds move across the sky. Rocks fall, or they roll down a hill. A bullet speeds toward a target. But the clouds, the rock, and the bullet do not cause their own motions. They are made to move by forces outside themselves. Hence their movements are not behavior.

[E]Only living things can show behavior because they alone can themselves move parts or all of their bodies. For this reason behavior is often called "the universal characteristic of life."

The characteristic of living things which causes them to be sensitive to conditions in the environment and enables them to react, that is, to respond to sound, heat, light, odors, pressure, and all other stimuli, is called irritability**[2] or sensitivity[3] (illustration, p. 357). Irritability is a unique and universal characteristic of protoplasm.

ALWAYS MANY STIMULI · For simplicity in the following pages, the stimuli described in any situation are referred to as if they occurred one at a time. Keep in mind, however, that every living thing is constantly receiving not one stimulus but many stimuli from its environment. Its response, therefore, is its reaction not to a single stimulus, but to all the stimuli that it is receiving. For example, in the battle of the cobra and the mongoose, each animal responded not only to the movements of the other, but also to the presence of stones, plants, and other conditions where it was fighting. Each was constantly reacting to all the conditions present. If another cobra or another mongoose had come upon the scene, each animal would have changed its reaction so as to respond to the entire new situation.

In any situation, moreover, a plant or an animal responds as a whole organism and not with only one part, or structure. Thus, though at one point in the mongoose-cobra struggle one of the animals might have seemed to respond to some movement of the other with a mere movement of its eyes, yet it was responding as a whole.

FACTORS AFFECTING BEHAVIOR · [E]Experiments have shown that the behavior of an organism in a certain situation is chiefly affected by three factors: (1) the strength of the stimuli, (2) the condition of the organism, including its previous experience and learning, and (3) the possible responses that it can make.

1. Strength of the stimuli. A plant which wilts in strong sunshine may become upright (turgid[4]) a little later when the sky becomes cloudy. An ameba will move toward weak acid solutions and away from strong ones. If your dog is asleep and you say its name in an ordinary tone, it may open its eyes and wag its tail. But if you shout its name loudly, it will probably jump. Doubtless you can think of other examples of responses that vary with the strength of the stimuli.

[1]Some scientists limit the use of the term *behavior* to the responses of animals that have nervous systems, and use *reactions* to designate the responses of plants and of animals without nervous systems. In this book, however, the term *behavior* is used to designate the responses of all plants and animals.

[2]*Irritability* (ĭr ĭ tȧ bĭl′ĭ tĭ).

[3]*Sensitivity* (sĕn sĭ tĭv′ĭ tĭ).

[4]*Turgid* (tûr′jĭd).

2. Condition of the organism. Hunger, maturity, and health, as well as bodily comfort in relation to temperature, light, and other factors, influence an animals' responses to stimuli. To illustrate: After an ameba has ingested a considerable amount of food, it will remain quiet for perhaps an hour. If food particles are brought near it, it will make no attempt to engulf them. Pavlov,[1] a famous Russian scientist, some of whose experiments will be described later, found that well-fed dogs would not react to stimuli as quickly as would hungry dogs. Hence he used hungry dogs in his experiments.

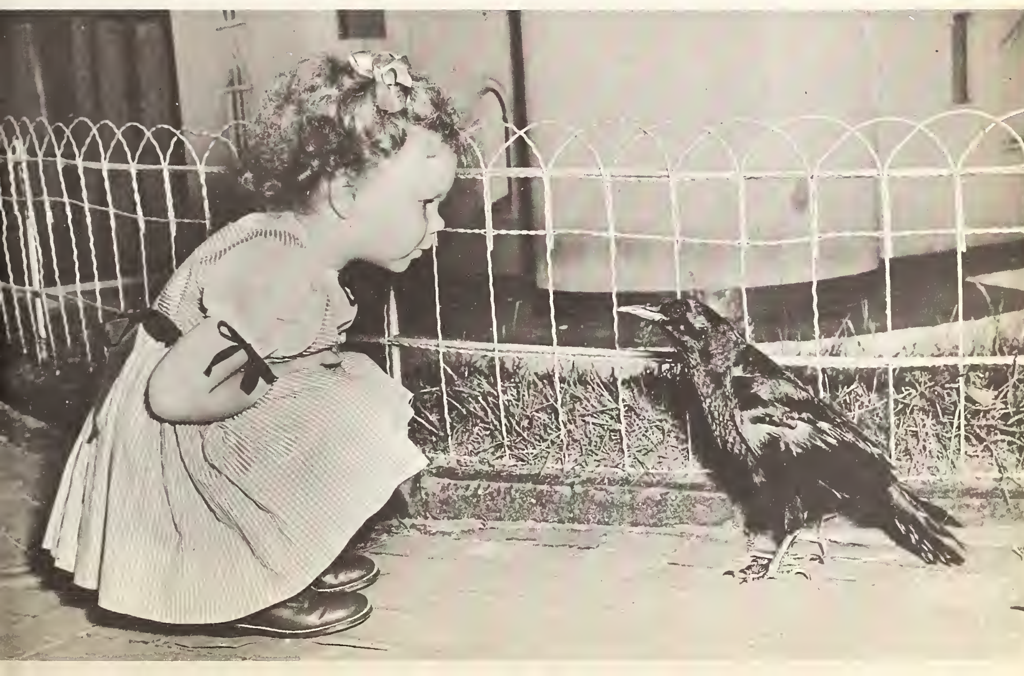
The young of the higher animals do not fear their enemies, as the adults do. They have not yet learned to do so. Perhaps you have found a young squirrel and have picked it up without its struggling or biting, as a full-grown squirrel would. A sick animal pays little or no attention to what is going on around it.

3. Possible responses. The behavior of even the simplest animals frequently indicates the making of "choices." Protozoans are often observed to react in one way when, under the conditions present, they might react in any one of several other ways. For example, an ameba, upon coming against a particle, may flow around it so as to engulf it, or may avoid it. A paramecium may move about or remain quiet. Such reactions, however, must not be thought of as being choices such as people make. The "choice" which a simple animal makes is likely to be merely a response to the strongest of all the stimuli that are present. There is, of course, no thought involved.

[1]*Pavlov* (pä'vlôf). Lived, 1849–1936.

What evidences of stimuli and responses do you see here? What evidences of irritability? Irritability does not necessarily indicate anger or ill temper. Explain

New York Zoological Society



In general, the higher the animal in the scale of life, the greater is the number of possible responses which it can make in a situation. For example, when you meet a strange dog, there are a number of reactions possible to both you and the dog. A choice has to be made. Not only must you decide what you are going to do, but the dog also must decide what it is going to do. The decision may be to attack, to be friendly, to run away, or to pay no attention to the other. Both your own decision and that of the dog will depend largely on the stimulus which the behavior of the other provides. The dog's decision, however, will not result from thinking or planning, as yours will (illustration below).

VOLUNTARY AND INVOLUNTARY BEHAVIOR · Did you ever do three things at once, such as whistling a tune while walking to school and thinking about something? Although your behavior at the moment included three entirely different types of activity, namely, whistling, walking, and thinking, yet you needed to pay attention only to your thinking. You were able to whistle and walk automatically, that is, without thinking about how to do them, or in fact thinking about them at all.

Actions like your whistling and walking, which require no conscious effort, are known as involuntary actions. Actions such as your thinking, which require conscious effort and attention, are known as voluntary actions.[1]

INVOLUNTARY BEHAVIOR · 1. **Tropisms.**[2] If you place a potted plant near a window, and observe it every day, you will note that the leaves on the side farthest from the window turn toward the window as they grow (illus-

[1]Some physiologists define *involuntary action* as an action performed by involuntary muscles and *voluntary action* as an action performed by voluntary muscles. The definitions used in this text, however, are those accepted by probably a substantial majority of all scientists.

[2]*Tropism* (trō′pĭzm).

What choices of behavior do the boy, cat, and turtle have here?

Press Association

Boyce Thompson Institute for Plant Research

The response of green plants to light (phototropism[1]) · All tropisms are believed to be due to certain hormones. In this case the hormone is a "growth substance" (an auxin[2]). For some reason not yet known, this plant hormone is more abundant on the shaded side than on the lighted side of a plant stem. Hence the shaded parts of the stem grow more rapidly than the lighted parts. As a result, the broad surfaces of the leaves are presented to the light. How is this behavior an aid to survival?

tration above). If you turn the plant around, its leaves will again grow toward the window.

If you release an imprisoned fly or a moth or even a bird, in a darkened room, it will go at once to a window. If, however, you release a cockroach or a "thousand-legged worm" (millepede[3]), in a lighted room. it will hurry to get into a dark spot.

Plants and animals make characteristic responses to gravity, just as they do to light. For example, if you cover some Lima-bean seeds with damp sawdust and keep them in a warm place, they will soon sprout. In a few days you will find that all the roots have turned downward, regardless of the positions in which the seeds were planted. If you then transfer these young plants to damp soil, no matter how you place them you will find that all their roots will again turn downward. You will find also that all their stems will turn upward as they grow.

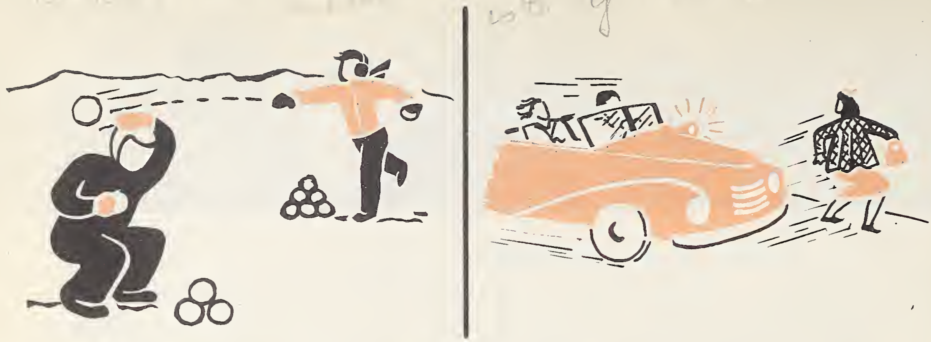
Whether a leaf-eating caterpillar is hungry or is not hungry determines the response that it will make to the pull of gravity. If a caterpillar that has not had food for some time is placed at the bottom of a stick, it will climb the stick. If then you turn the stick end for end, the animal will turn, too, and will again move upward. A well-fed leaf-eating caterpillar, however, will, under the same circumstances, behave in exactly the opposite way.

Responses such as those to light (phototropism) and gravity (geotropism[4]) just described are classed as tropisms. Tropisms are the simplest behaviors. A tropism is an involuntary response in which an animal,[5] a plant, or a part of a plant moves toward or away from a stimulus (illustration above).

Positive and negative tropisms. A turning toward a stimulus is a positive tropism. A turning away is a negative one. Thus the

[1]*Phototropism* (fō tŏt′rō pĭzm).
[2]*Auxin* (ôk′sĭn).
[3]Page 531.

[4]*Geotropism* (jē ŏt′rō pĭzm).
[5]The scientific name for the responses of animals that correspond to tropisms in plants is *taxes* (tăk′sēz); singular, *taxis* (tăk′sĭs). For simplicity here, such reactions of both plants and animals are grouped as tropisms.



Can you explain these drawings, using the terms *stimulus*, *response*, and *reflex action?*

downward turning of the roots and the downward movement of the well-fed caterpillar, in the direction of the pull of gravity, are positive tropisms. The upward turning of the bean stems and the upward movement of the hungry caterpillar, away from the pull of gravity, are negative tropisms. The movements of certain insects toward light and the turning of plant stems toward the same stimulus are positive tropisms. The movements of cockroaches and millepedes away from light are negative ones.

Various tropisms. A number of stimuli, besides gravity and light, produce tropisms. When the stems of pole bean or pea plants touch an upright stake or string, they turn so that they go round and round it as they grow taller. Ants follow their burrows by touching the walls with their antennae. These behaviors of the climbing plants and the ants are responses to touch, or contact (thigmotropisms[1]). You may have observed that trout and some other kinds of fish, at rest in a running stream, have their heads upstream. This is a response to the current (rheotropism[2]). Plant roots turn so that they grow toward wetter parts of the soil (hydrotropism[3]), as you may have observed if the drains from your home have ever become clogged by tree roots which grew through cracks or holes in the pipes. Other tropisms of plants and animals include responses to certain chemicals (chemotropisms[4]), reactions to heat (thermotropisms[5]), and reactions to color (chromotropisms[6]).

[E]In general, the tropisms of plants are similar to the corresponding reactions of animals, except in two respects: (1) the plant reactions take place along with growth and control its direction, whereas those of animals do not, and (2) only a part of a higher plant grows toward or away from a stimulus, but animals change their locations.

2. Reflex actions. If you touch a crawling caterpillar, it stops instantly, rolls into a ball, and becomes motionless. If you pet a cat, it arches its back under your hand. If somebody suddenly shouts loudly in your ear, you instantly "jump" and close your eyes (illustration above). If you put your hand upon

[1]*Thigmotropism* (thĭg mŏt′rō pĭzm).
[2]*Rheotropism* (rē ŏt′rō pĭzm).

[3]*Hydrotropism* (hī drŏt′rō pĭzm).
[4]*Chemotropism* (kĕ mŏt′rō pĭzm).
[5]*Thermotropism* (thẽr mŏt′rō pĭzm).
[6]*Chromotropism* (krō mŏt′rō pĭzm).

unlearned & immediate

something hot, you jerk it away before you have had time to think about removing it.

Such reactions as these are reflex actions, or reflexes. A reflex is an immediate, uncontrolled response to a stimulus. It is like a tropism in being involuntary, unlearned,[1] and automatic. It is unlike it in being, in general, much more rapid and immediate. Also, only animals have reflexes, for reasons that will be explained later.

All animals except the simplest ones have reflexes. Human beings have many.

A reflex, once started, is always completed. Suppose you put something into your mouth and started to swallow it, when suddenly you realized, to your horror, that it was a deadly poison. You would not be able to stop the swallowing movements after they had started, even though you knew that your life depended on doing so. Have you ever accidentally inhaled some pepper? No matter how hard you may have tried to avoid sneezing, you probably sneezed violently, nevertheless.

3. Instincts. Animals show an amazing variety of complex behaviors which scientists call instincts or instinctive reactions. A young spider, for example, will grow to a certain size and then spin a web. Each kind of spider has its own characteristic form of web, which it is able to make the first time that it tries to do so. Every kind of nest-building bird makes a certain type of nest. After the eggs have been hatched, the parent birds give the young ones only the kinds of food and care that such birds must have.

The tendency to perform an instinctive action is often so strong that the action will follow a stimulus that only slightly resembles the normal one. To illustrate, after a hen has finished her laying season, she is ready to incubate her eggs. If the eggs have been removed, she will nevertheless sit in the empty nest. In one experiment, while a sitting hen was away from her nest to get food and water, white door-knobs were substituted for her eggs. Thereafter the hen behaved toward the door-knobs exactly as she would have behaved toward eggs. She not only covered (sat on) them, but turned them over with her beak every day.

Another hen, which had been deprived of her chicks, found in the barn a litter of kittens. She covered them at once and continued to do so most of the time, thereafter, for a number of days, as if they were chicks. Whenever the mother cat came to feed her kittens, the hen perched upon the cat and thus sat on the whole family.

Instincts, a series of reflexes. An instinct is believed to be a series of reflexes. Each series is started by a definite stimulus. Each response, or completed act of the series, serves as the stimulus to the next reflex, as the following examples indicate:

In the fight between the mongoose and the cobra each situation, as the battle progressed, served as a stimulus for the next response. When a hen is ready to sit, the eggs serve as the normal stimulus for the nesting behaviors. After the chicks are hatched, their movements stimulate the hen to leave the nest and to search for food for her brood.

Are instincts unlearned? Such instinctive acts as those performed by spiders and relatively simple animals would seem to be unlearned. It is difficult to imagine how they could be otherwise. Recent study, however, has shown that many instinctive behaviors of higher animals have been at least partly learned. In fact, incidents such as those that follow have led some scientists to question whether any of the reactions of adult higher

[1]Many psychologists use the term "*ingrained* response" instead of "*unlearned* response."

animals, which are classed as instincts, are entirely unlearned:

A mother tiger was observed to bring, to her four cubs, prey which she had killed. They were obviously hungry; yet she did not let them eat immediately. Instead, she leaped upon the dead animal, growling savagely and sinking her teeth into its throat. The young ones imitated her. Through practice they learned to perform with increasing skill these acts, which they would later have to perform in capturing prey.

One would expect that the sea otter (illustration, p. 120), a mammal that spends practically all its life swimming or floating on the surface of the Arctic Ocean, would swim instinctively. But it does not. The young ones cannot swim at all. Each mother otter teachers her baby to swim by a long process of training. This training takes place out in the ocean during many weeks when the only place where the young otter can be out of the water is on its mother's breast as she floats on her back (illustration below). When young robins and many other young birds have reached the right stage in their development, the mother birds teach them to fly.

Instincts in man. Scientists have devoted a great amount of time and energy to the study of instincts in man. In spite of this fact, there is little about the subject upon which they agree. Certain actions of young babies, however, are usually classed as instincts. If a round stick is pressed against the palms of a new-born baby's hands, the baby will grasp it. If then the stick is raised, the baby will hang from it by its hands, thus supporting its entire weight for several seconds. If the area around a baby's mouth is touched, it will try to get the object which touches it into its mouth. If it succeeds, sucking reflexes are immediately started.

A polar-bear cub does not swim instinctively. It has to be thrown in and "fished out" by its mother a number of times before it learns to swim. Can you give another example of an instinctive action that seems to have to be at least partly learned?

Three Lions

VOLUNTARY BEHAVIOR · Voluntary actions are among our most important and frequent behaviors. They include such behaviors as looking for a job, solving a problem in mathematics, going to a motion-picture show, and deciding what clothes to wear (illustration, p. 364).

Voluntary behavior involves the making of choices, or decisions. In every case one has to think about what one might do and then decide what one is going to do. In getting a job, for example, you have to decide first whether you want a job; then, if you do, what kind of job you want. After you have decided that, you have to decide where to look for the job and how to approach the employer. Every one of these choices of action, in turn, requires careful thinking. You plan your behavior after you have considered all the conditions which you think will be involved.

2. How Are Certain Behaviors Related to Survival?

When ground squirrels, prairie dogs, and many other burrowing mammals sense danger, they scamper into their burrows. Other animals try to escape from danger by running, crawling, flying, or swimming away.

When a fire passes through a forest, animals of many kinds sense the danger and at once attempt to flee. Their fear reaction to the fire is so much stronger than their usual reactions toward one another that they seem not to notice their usual prey or enemies. A porcupine hurries along at top speed, a scant two miles per hour. A bear lumbers by, but is passed by a deer and a cougar, covering the ground in great leaps, side by side. Weasels, squirrels, and other forest animals strain in their efforts to run faster than they have ever run before.

"FIGHT OR FLIGHT" · If a dog comes suddenly upon a cat, the cat is likely to arch its back, spit at the dog, and prepare to fight. If it has a good chance to escape, however, it probably will run away or else climb a tree. Many other animals, like the cat, will fight fiercely if they cannot escape from larger animals. You have probably heard the expression "fight like a cornered rat." Most animals, however, would rather escape from their enemies, if they can, than stay and fight them.

REMAINING MOTIONLESS ("FREEZING") · Animals that have protective coloration[1] exhibit the opposite behavior from running away to escape predators. Instead, they remain motionless, or "freeze." Thus they often escape by not being discovered. Early pioneers in the Colorado mountains, who depended on snow-shoe rabbits chiefly for their meat supply in winter, relate that they were able to discover these snow-white animals, motionless in the snow, only by seeing their bright, wide-open eyes.

BEHAVIORS ASSOCIATED WITH LIFE NEEDS · **1. Securing food.** Practically all living things exhibit characteristic and often unique behaviors associated with food-getting. Behaviors of green plants in relation to photosynthesis have already been described. Such one-celled and colonial organisms as *Euglena*[2] and *Volvox*[3] move to locations where there is the proper amount of sunshine for photosynthesis. Many of the simpler animals, such as paramecia and sponges,[4] secure food by moving their hair-like structures (cilia and flagella) in such a way as to make currents in the water, which carry food particles into their bodies.

The animals that are complex enough to have sense organs use them in locating and securing food, as a few examples will indicate.

a. Use of the sense of hearing. In the jungles of Brazil paradise nuts mature on trees in a pod-like structure resembling a good-sized urn. When the nuts become ripe, enough gas is formed inside the structure to blow off the top with a loud pop and to scatter the nuts all about. The monkeys hear the pop and hurry noisily to the spot to get the nuts.

If you have had "farm experience," you have no doubt seen chickens and pigs hurry, when they are called, to the places where they are usually fed.

b. Use of the sense of sight. It would be difficult to think of any animal that has eyes that does not make use of them in finding and securing food.

c. Use of the sense of smell. If you offer a

[1]Pages 203 and 545.

[2]Page 568. [3]Page 566. [4]Page 515.

dog, a cat, or a horse some food, it will smell the food carefully before deciding whether or not to eat it. Wolves and many other animals track their prey by the sense of smell.

d. Use of the sense of taste. Some water animals, such as crayfish, crabs, lobsters, and other crustaceans,[1] as well as most fish, are believed to find their food through senses which correspond to our sense of taste or smell, or both. For example, if you drop a meat bone into a creek where there are crayfish, you will soon see them hurrying along the creek bottom toward the bone from considerable distances downstream.

2. **Securing oxygen.** You have probably observed goldfish gasping near the surface of the water in the goldfish bowl in their efforts to secure enough oxygen. If you fall into deep water, your natural reaction is to struggle to the surface for air.

[1]Page 530.

3. **Maintaining necessary bodily temperatures.** Did you ever run fast, beat your arms against your body, or stamp your feet, to get warm? Doing any of these things stimulates the circulation. Thus more food and oxygen are brought to the cells and the rate of the oxidation of food is increased, with a consequently greater production of heat energy.

In cold weather birds fluff out their feathers and thus reduce the loss of heat from their bodies. Kittens, puppies, and other animals born in litters crowd together to keep warm.

What voluntary decisions have to be made in each of these four situations?
Most scientists believe that only man, and *perhaps* the higher apes to a slight extent, exhibit voluntary behavior

It is amusing to watch those on the outside crawl under the others to reach a warmer spot. During cold weather bees in a hive cluster together. In warm weather, however, they sometimes cause forced ventilation, and thus lower the temperature, by beating their wings, all at the same time and in the same way.

Many cold-blooded animals, such as the snakes of the Temperate Zone, toads, frogs, and other reptiles and amphibians, hibernate during the winter. The snakes find a deep crevice, a crack in the earth, or a cave. Sometimes hundreds will coil themselves together in one den. Frogs and toads bury themselves during the winter in the mud at the bottoms of streams and ponds.

A few warm-blooded animals hibernate. The most familiar example is probably the black bear. It seeks a cave, a hollow log, or similar shelter early in winter and remains there during the cold months.

Hibernation serves various purposes: (1) It prevents many kinds of animals from freezing to death. (2) Hibernation enables animals to remain relatively inactive, and thus to keep alive on the energy already stored as fat in their bodies, during the season when they could not secure food. (3) Hibernation provides animals with the protection of a shelter during the time when they are inactive and not able to protect themselves from enemies.

4. Conserving body fluids. The hot, dry weather of summer causes many animals to enter a state (estivation[1]) resembling hibernation. These animals include ones that are not able to roam far in search of water, as large mammals can, when the ponds dry up and the habitat becomes very dry. Such animals, therefore, can survive only if their body fluids are conserved. Snakes and lizards crawl into holes in cool, shaded places and become dormant. Land snails secrete coverings which close the open ends of their shells and thus prevent the evaporation of moisture from their bodies. Frogs, toads, and other amphibians, some turtles, and even some fishes bury themselves in the mud of pond bottoms. When, usually in the autumn, the rain-fall restores enough water to the habitat, the dormant animals again take up their normal activities.

[1]*Estivation* (ĕs tĭ vā′shŭn).

5. See legend of illustration on page 367.

REACTIONS UNFAVORABLE TO SURVIVAL · The illustrations given on the preceding pages are only a few of hundreds that might be given which help to establish this principle: Organisms react in ways that increase their chances of survival. Like most biological principles, however, this one has some exceptions. Occasionally an organism will make an involuntary response that results in its injury or death. For example, a paramecium will move into a strong solution of copper sulfate, even though the solution will kill it.

Even higher animals sometimes react in ways harmful to themselves. To illustrate: Frogs and toads snap at small flies and other insects that move near them, and thus they secure food. This reaction is a reflex. When the right stimulus is presented, these animals have no choice but to snap at whatever is causing the stimulus. One experimenter surrounded a fly with sharp needles, then moved it near a frog. The frog snapped at the fly again and again, even though in doing so it received severe injury from the needles every time. Horses rescued from burning stables have been known to run back into the fire unless prevented.

BEHAVIORS ASSOCIATED WITH CONTINUING THE RACE · **1. Fighting.** It is not unusual for hunters to find two deer skulls with the horns locked together. The locked horns

Ackerman, from United States Department of Agricultur

How are the behaviors of these young people in plowing related to life needs? How does this picture furnish evidence supporting the statement "Of all living things, only man makes long-range plans"?

can be accounted for in this way: In the autumn, during the mating season, the male deer fight one another fiercely. Sometimes during the combat their horns become locked together and cannot be pulled apart. Then the two deer, unable to defend themselves or to run away, fall an easy prey to a panther, a lynx, or other carnivorous animal, or they slowly starve to death.

During their mating seasons not only male deer, but most male mammals, and many male birds as well, fight with other males of their kind. During such fights, the females, which are often present, exhibit no concern over the fortunes of either fighter. Such combats end when one of the males either is killed or realizes that he is beaten and manages to run away. The females then accept the victor as their mate.

2. **Migrating.** Evidence obtained from recent studies indicates that some, if not most, migrations are related more closely to reproduction than to lack of food or other causes. Birds migrate from the south to the localities where they raise their young (illustration, p. 26). Salmon, smelts, and other fish migrate to their spawning grounds. Land crabs of Jamaica migrate once a year from the interior of the island to the beaches where they breed. They take the most direct route pos-

sible in going and coming and consequently scramble over all obstacles, such as rocks, fallen trees, and, if they can, even houses that may happen to be in their paths.

3. Choosing mates. With the exception of a few birds and mammals, no animals display any behaviors that indicate that they choose their mates. The penguin is one of these exceptions. The male penguin decides upon one of the females in the flock and pays her amusing "court." He struts and capers around her, trying in every way to attract her attention. Meanwhile she appears not to be aware of his existence. Finally he places a bright pebble or other object at her feet. She regards it for a moment, apparently making up her mind. If then she turns away, leaving the object where it is, the male at once ceases his efforts to attract her. He seems to infer that he has been rejected and soon transfers his attentions to another female penguin. But if she picks up the object, her doing so is apparently a sign of her acceptance of him as her mate for life.

Even such complex behaviors as those just described cannot be considered as indicating any true planning or reasoning such as human beings use in solving their problems. Most biologists would conclude that the penguins' reactions are instinctive.

Most birds and mammals remain with their mates only while the young are growing to maturity. Such animals usually have a different mate each time that they produce young. Ostriches, however, and a few other birds besides penguins have the same mate for life. So also do some mammals. The silver fox is one of these. Breeders of these foxes have learned that a pair of them must be allowed a long period in which to become acquainted before they will mate. They must never be put into separate kennels. Only by heeding these rules can the owners of silver-fox farms get breeding pairs.

4. Providing parental care. The human baby at birth is almost entirely helpless. So also is a new-born kitten, puppy, or other mammal. So also are chickens and most other newly hatched birds. If the parent mammals and birds did not protect their offspring (young), and also provide them with warmth, food, and other life necessities, the babies would soon die.

In contrast with these helpless offspring

5. Securing water · Usually the natural reactions of an organism are such as to increase its chances of survival. Can you give an original example of this principle?

A. M. Deig

National Parks Bureau, Canada

Raccoon at the door of its den in a hollow log · To which of the behaviors associated with life needs do you infer that this picture is related (p. 364)? Explain

are the progeny (young) of most of the amphibians, reptiles, and fishes, and of all the invertebrates except bees, ants, and a few other arthropods. Their young are able to take care of themselves completely from the time that they are hatched or born. If they could not, they would die and their kinds would become extinct almost at once because their parents give them no help in surviving. These parent animals prey as readily upon their own eggs or their own young as upon other eggs or organisms.

All the behaviors that have to do with taking care of the young until they are able to take care of themselves are included in the term *parental care* (illustrations, pp. 369, 370).

5. Distracting the attacker. If, when an enemy appears, it is not possible for a mother animal either to take her young to a safe place or to fight, she sometimes exhibits another kind of protective behavior. The following quotation provides an example:

I have seen, on the plains, the gazelles play this game when I have unknowingly come upon the spot where they were hiding their newborn fawn. They would dance to you, step up before you, jump, caper or pretend to be lame and unable to run, all to distract your attention from their young. And suddenly, actually under the hoofs of your horse, you saw the fawn, immovable, the small head stretched out flat on the grass, lying low for his life while his mother dances for it. A bird will do the same tricks to protect her young ones, flap and flutter and even cleverly act the role of the wounded bird which trails her broken wing on the ground.[1]

[P] In general, most of the behaviors that are classed as parental care are exhibited by the mother animals (illustration, p. 369). There are, however, many exceptions to this principle. The male Chinese pheasant takes all the care of the first brood in a season, while the female is hatching the second. Deer, cattle, sheep, and other mammals that live in herds or flocks exhibit a division of labor with respect to parental care between the male that rules a herd or flock and the females in it. The male watches for enemies and, when necessary, leads the others in flight from danger, or he fights to protect them. The females, thus freed from most of the need of protecting their offspring from enemies, can give the young the individual care that they require.

SPECIALIZED STRUCTURES AND SPECIALIZED BEHAVIORS · One fir tree looks much like every other fir tree. One collie dog varies from another collie dog only in minor respects. In general, all the plants or animals of the same kind vary relatively little in structure.

[1] Isak Dinesen (pen name of Baroness Karen Blixen), *Out of Africa*, p. 133. Quoted by permission of Random House, Inc., New York, and Putnam & Company, Ltd., London.

United States Fish and Wildlife Service

The catbird (*A*) is an example of an altricial[1] bird. The Canada goose (*B*) is an example of a precocial[2] bird. Look up *altricial* and *precocial* in a dictionary and in other available sources so as to be able to explain them and give other examples of each. The mound-building bird of Australia builds a mound of decaying organic matter, lays its eggs on the mound, and covers them. It gives them no further care. The young birds, when hatched, are fully feathered and can fly. Is the mound-building bird altricial or precocial? Explain

[1]*Altricial* (ăl trĭsh′ăl). [2]*Precocial* (prē kō′shăl).

One fir tree has about the same behaviors as every other fir tree. The behavior of one collie dog is about the same as the behavior of another. In fact, it is generally true that living things of the same kind must display about the same behaviors because their structures are so nearly the same.

There are, however, some exceptions to the preceding statement. These exceptions include (1) the "social insects," such as ants and bees, and (2) man. Social insects of the same kind vary in structures and consequently in behaviors. Human beings, although alike in structures, vary greatly in their behaviors.

SOCIAL INSECTS · A hive of honey-bees or a colony of common ants is composed of several "castes," or special groups (illustration, p. 373). In the same bee-hive there is one female, the queen; there are usually many males, or drones; and there are a great number of workers. The workers are female bees whose sex organs are not developed. These castes of bees differ considerably in their structures, and they differ entirely in their behaviors. The queen's only function is to lay eggs. A drone performs no function except that of making fertile the eggs of the queen. The workers gather the food, build the comb, take care of the young, and perform all the other work of the colony.

An ant colony has a social structure made up of castes, somewhat similar to that of bees. Within the same colony there are females, males, and ants with undeveloped sex. The last group includes soldiers, great numbers of workers, and sometimes other castes. A person who has studied ants can readily tell the members of one caste from those of another by their appearance, for they differ in structure conspicuously (in ways that are readily observed). Their specialized behaviors are closely related to their specialized structures. The division of labor among the different castes of ants and bees is of great importance to the survival of these kinds of insects.

MAN · Today, as in past ages, all men are about the same in structure. There is nothing in their appearance that would indicate their specialized behaviors. Twin brothers may look so much alike that nobody can tell them apart; yet one may be a miner and the other an airplane pilot. The men that go to work on the same bus in the morning will engage in as many different behaviors during the day as there are differences in the kinds of work that they do. There is hardly

Keep watch for examples of parental care among birds and mammals. Take careful notes of your observations as a basis for a report in your class or in the science club

Keystone

any limit to the number of examples that could be given of the specialized behaviors of human beings.

[E]All living things, including man, are limited in their behaviors by their structures and their environments. Through his ability to specialize in behavior, however, man not only can adapt himself to a wider variety of environments than any other organism, but also can greatly change his environment. For example, engineers build irrigation projects and thus bring water to desert regions, enabling farmers and fruit-growers to develop fertile farms and orchards. Sanitary engineers and builders change slums to pleasant homes. People with highly developed specialized behaviors work together for the common good. Thus they carry on social division of labor, and hence constantly increase man's control of living and non-living things. Further advancement along the lines of cooperation (working together) for the common good is the basis for man's continued survival.

INDIVIDUAL AND GROUP WELFARE · [E]In his earlier history man solved most of his problems without reference to others, as most organisms have always done. Even in pioneer days the trapper or hunter managed to survive chiefly by the effectiveness of his own behaviors. In the modern world, however, man cannot solve his problems without considering the effects of his actions upon others. His behaviors affect many other people. He must therefore control his behaviors so that they contribute not only to his own advantage, but also to that of others. The behaviors of even a great group, such as a nation, must contribute not only to the welfare of the group itself, but also to the welfare of other nations.

Checking What You Know

BIOLOGICAL FACTS · (*Do not write in this book.*) **Pages 354–362.** **1.** Hearing a mosquito "sing" is a stimulus; slapping at it is a --?--.

2. *Few* stimuli act on an organism at any one time, and an organism reacts to *only one* of these.

3. State and give one illustration of each of the conditions that determine how a plant or an animal will react to a stimulus.

4. Brushing off a fly that lights on your face is an example of a *voluntary* action. Going to another room to get a drink is an example of an *involuntary* action.

5. An example of a reflex action is (1) the flying of a moth directly to a light; (2) dodging a ball that you see coming straight toward your head; (3) the migrating of robins in the autumn; (4) throwing a stone at a post; (5) choosing a necktie.

6. Which one of the five reactions stated in the preceding item is an instinctive reaction? Which is a tropism?

Pages 363–371. **7.** Most animals will *fight* a more powerful enemy if they can, but they will *run away* if they must.

8. It is difficult to see a motionless toad in its usual habitat because the toad has --?--, or --?--.

9. *Few* behaviors of plants and animals are closely related to life needs.

10. State three advantages which animals may derive from hibernating.

11. *All* reactions of living things increase their chances of survival.

12. State at least four behaviors that are related to race survival, and give one illustration of each.

13. An example of a kind of organism that has different castes which have characteristic behaviors is (1) a maple tree; (2) a bacterium; (3) a protozoan; (4) an invertebrate; (5) a vertebrate; (6) an ant.

14. A kind of organism the individuals of which vary relatively little in structure, but greatly in behavior, is --?--

BIOLOGICAL PRINCIPLES · 1. Living things have an effect on the environment, and the environment affects living things.

2. Plants and animals respond to various kinds of stimuli in their environment.

3. In general, the behaviors of the simpler animals are much less complex than those of the higher ones.

4. Behaviors of living things are adaptations which enable the organisms to survive and to continue their kinds.

5. All protoplasm has the characteristic of irritability.

6. Certain associations of living things—for example, community, or social, life—are the result of a struggle for survival and are an aid to survival.

7. Protective adaptations are an aid to survival.

8. A reaction is successful if, directly or indirectly, it increases the organism's chances of survival.

BIOLOGICAL TERMS

**irritability **response **stimulus

Applying and Extending What You Know

AS SCIENTISTS WORK AND THINK · 1. On page 371 of this chapter is the following principle: All living things, including man, are limited in their behaviors by their structures and their environments. Read again the rest of the paragraph, in which some of man's accomplishments are mentioned. Which of the scientific attitudes did the men who accomplished these important tasks need to possess?

2. Using the elements of scientific method, plan an experiment to determine whether or not fish in the classroom aquarium can be taught to respond to some stimulus, such as tapping with a pencil point on the sides of the aquarium. Indicate which of the elements of scientific method you are using at each step of your experiment. Indicate also which you are not using.

3. Some hand-raised thrushes, jack-daws, sparrow hawks, and martins made no move when water was merely placed near them. But as soon as the investigator rippled the water with her finger, the birds immediately got into the water and bathed in the same way as would wild adult birds of the same species. What inferences do you draw from this incident? How is it related to the discussion of instincts and reflexes on pages 360–362?

CONSUMER BIOLOGY · Which of the tropisms described on pages 358–360 should be considered by the buyer or the builder of a house?

APPLYING YOUR KNOWLEDGE OF BIOLOGY ·
1. Name several different kinds of stimuli to which you have responded today. How did you respond to them?

2. Name several acts that you have performed today which are examples of voluntary behavior. Name several others which are examples of involuntary behavior.

3. The migration of lemmings is an example of what kind ot behavior?

TOPICS FOR INDIVIDUAL STUDY · 1. In a book such as Fabre's[1] *Life of the Spider* or Maeterlinck's[2] *Life of the Bee* find some examples of the behaviors of spiders or bees. Prepare a report of your reading.

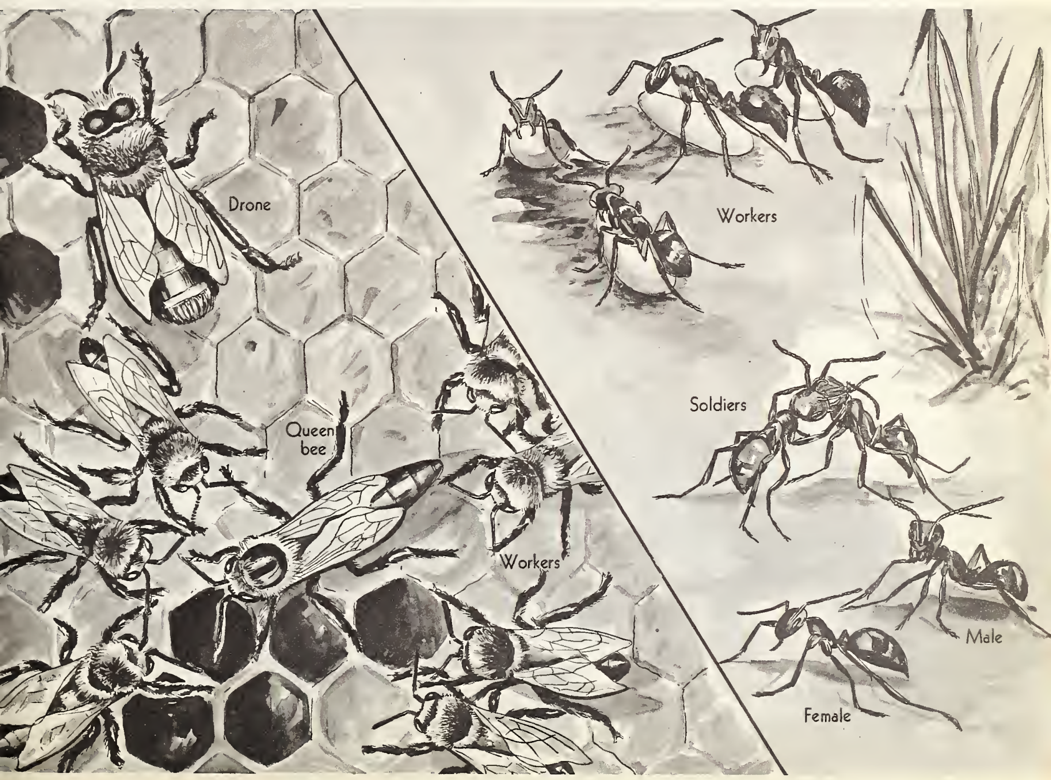
2. Look up the behavior typical of very young babies, in a book such as Arnold Gesell and Frances L. Ilg's *Infant and Child in the Culture of Today* (Harper Brothers). Take notes on the development of a baby's behavior from the time it is born until it is a year old. Make a report in your class, your home room, or your science club.

EXPERIMENTS · 1. How does a frog respond to certain stimuli? Put a living frog in a small battery jar or other transparent vessel containing a small amount of water. Why is the water necessary? Touch the frog's eye lightly with the eraser end of a pencil. What is the frog's response to this stimulus? Do you think this response is a tropism, a reflex, an instinct, or a voluntary action? Explain. Apply the stimulus a little more strongly, being careful not to injure the frog's eye. How does the animal respond now?

Using the sharp end of the pencil, or a dissecting needle, tickle the left nostril of the frog. Be careful not to injure it. What happens? Repeat this stimulus, meanwhile watching the left eye of the frog. Describe and explain what you observe. Pick up the frog, putting the thumb of your hand on one side of its body and the

[1]*Fabre* (fȧ'br). [2]*Maeterlinck* (mā'tĕr lĭngk).

Castes of bees and castes of ants · The different castes among social insects result in a wider division of labor than would otherwise be possible. Having different castes increases the chances of survival of the whole colony. Can you explain these statements?



fingers on the other. Hold the frog in this way for a while, but not too tightly. Again be sure that you are not hurting it. Does it begin to croak? If so, what is the stimulus?

With the dissecting needle or sharpened pencil point lightly scratch one side of the frog's body. How does the frog respond? What might be the value of such a response to the frog? Wrap a bit of cotton on the end of the dissecting needle or on the pencil point. Dip the cotton in some ammonia and touch the cotton to the side of the frog's jaw. What happens? Explain.

2. What are some reactions of the sensitive plant? Obtain one or two sensitive plants (*Mimosa pudica*) from a local dealer or from a scientific supply house. Touch one of the buds on the end of a branch. What happens? If nothing happens, pinch one of the end leaflets with your fingers. What kind of response do you note? How do you account for the reaction of the plant? Light a match and apply the flame to the end of a branch of another mimosa plant. What is its reaction? What does this reaction indicate?

Put one of the sensitive plants into a refrigerator in which the temperature is about 40° F. After it has been in the refrigerator for one hour, touch one of the end leaflets. How does its response now compare with the response that you got when you first touched one of the branches? Put the plant back into the refrigerator for another hour. How does the plant respond now when you touch it? What do these experiments indicate about the effect of temperature on the sensitive plant's ability to respond? Did you have controls in any of these experiments with the sensitive plant? If not, how would you introduce controls?

WHY NOT BECOME A NATURALIST? · **1.** How do certain plants react to the absence of light? Find some red clover in your neighborhood and notice its leaves during the day. Make a second observation after the sun has set, using a flashlight. What change has taken place? Make a similar set of observations of a dandelion or a cactus flower. Repeat your observations two or three days in succession. Does the same thing happen each time? What conclusions can you draw from your observations? Which of the elements of scientific method did you use in this activity?

2. What observations of animal behaviors can be readily made? Take one or several "hikes" for the purpose of observing the behaviors of birds, squirrels, and other kinds of wild life. Try in each case to determine what the stimulus is that causes the response. You will not be able to discover the stimulus in every case. Make a record of your observations and from this prepare a report to be given in class, in your home room, or in the science club.

COMMUNITY APPLICATIONS OF BIOLOGY · **1. Observing the stimuli that cause responses.** The next time you go to a circus, see whether you can detect the stimuli that are used in the various trained-animal acts. A report of these observations would provide an excellent theme for your English class.

2. Observing zoo animals at feeding time. Visit a zoo at the time when the animals are being fed. Make notes of their various behaviors. Are there any behaviors that suggest a competition for food or a struggle for survival? These observations could be made into an interesting article for your school paper.

BIOLOGY IN THE NEWS · Watch the newspapers and news magazines that you read for stories about unusual behaviors of animals. You may find a story of a female cat which has adopted a litter of skunks; of a bird that attacks people passing by its nest which is close to the sidewalk on a busy street; of a dog that has helped to rescue persons from danger. Post the best ones on the bulletin board.

14

HOW BEHAVIORS TAKE PLACE

1. What Structures Are Involved in Behavior?

If you speak to a friendly dog, it will probably respond by wagging its tail. Even though only one part of the animal, the tail, is seen to respond, nevertheless many parts of its body must be involved in order that a stimulus that reaches its ear may result in a response by its tail (illustration, p. 376).

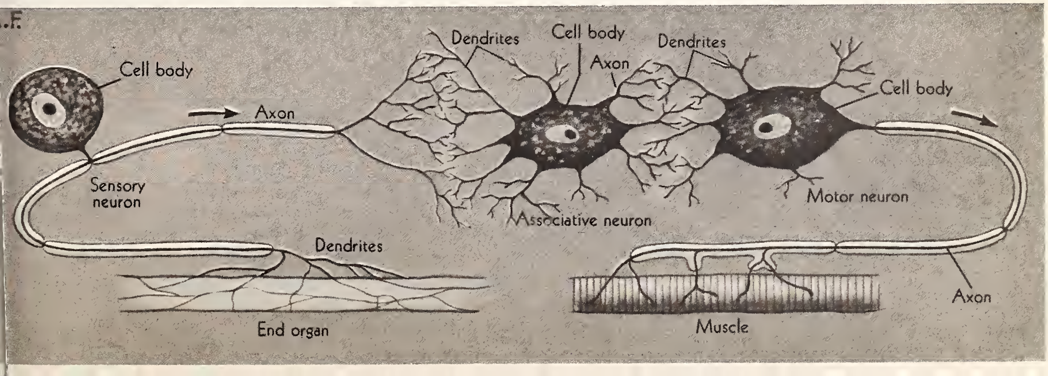
Suppose that you are playing catch. As the ball approaches you, it provides a stimulus only to your eyes. But this stimulus is transferred through your body, with the result that your feet, legs, arms, hands, and other organs react in the ways necessary to enable you to catch the ball.[1]

In order to understand how such complex reactions as those just described can occur, one must know (1) what structures are involved when an organism responds to a stimulus, (2) how these structures function, and (3) how all the structures co-operate to produce the final behavior.

[1]Page 356, paragraph 1 (second column).

STRUCTURES INVOLVED IN BEHAVIOR · [E]In all animals except the simplest ones—namely, the protozoans and the sponges—there are three body systems that are involved in producing behaviors. These are (1) the nervous system, (2) the endocrine system, and (3) the muscular system. The nervous system has three functions. These are (*a*) to receive stimuli, (*b*) to transmit the effects resulting from stimuli to the various muscles and glands, and (*c*) to cause the resulting reaction to take place. The muscular system has the function of producing all the movements that make up the animal's behaviors. The muscular system, and the endocrine system as well, are controlled by the nervous system.

Various types of neurons · Note that the axon of one cell does not touch the dendrite of another. In what ways are neurons like all other cells?



Toni Fris

What structures of the little girl do you think are involved in her reaction to the cow?[1]

[1]From *A Child's Garden of Verses*, a U. S. Camera book.

THE UNITS OF THE NERVOUS SYSTEM, THE NEURONS · All the parts of the nervous system of an animal are made up of highly specialized cells, called nerve cells or neurons.*[1] In one of the higher vertebrates the neurons may number many billions. The human brain alone is composed of more than twenty billions.

Neurons vary considerably in form. They are microscopic. In some the axons[2] and dendrites[3] may be no longer than the nucleus. In others these thread-like extensions may be several feet long, and yet not more than a thousandth of an inch thick. A nerve is made up of the axons and dendrites of many neurons together, somewhat like a cable composed of separate strands.

Neurons are specialized; that is, there are three different kinds, each having its own special functions. These kinds are sensory neurons, motor neurons, and associative neurons (illustration, p. 375). The sensory neurons receive stimuli and hence are the ones that enable an animal to become aware of conditions in its environment. The motor neurons transmit impulses to muscles and glands and thus start the reactions. The associative neurons carry impulses between sensory and motor neurons. Many associative neurons serve thus when several parts of an animal need to act in response to a single stimulus.

THE NERVOUS SYSTEM · The nervous systen of a mammal consists of the central nervous system and the autonomic[4] nervous system. The central nervous system is made up of the brain, the spinal cord, and the nerves leading to and from them. The autonomic nervous system includes certain masses of neurons called ganglia[5] and the nerves leading to and from them.

1. The central nervous system. *The brain.* The important divisions of the brain are the cerebrum,[6]** the cerebellum,[7]** and the medulla oblongata*[8] (illustration, p. 378).

The outer portion of the two halves, or hemispheres, of the cerebrum is a layer called the cortex or cerebral cortex[9] (illustration, p. 379). The cortex consists almost entirely of the nuclei of neurons. These nuclei are gray in color, and hence the cortex is called the "gray matter" of the brain.

The cortex has many wrinkles, or folds (convolutions[10]). Because of them it has a far greater surface area than it would have if it were smooth. If you were to compare the cortex of the brain of man with that of the brain of any other vertebrate, you would find that the human cortex has many more folds. Consequently it has a much greater surface for its volume and weight.

The diagram on page 379 shows the areas of the cerebral cortex where sensations are received from some of the sense organs, and where various kinds of actions are controlled. The association areas are believed to be the centers of the higher thought processes—thinking, planning, remembering, and problem-solving.

Experimenters have removed the cerebrums of birds, cats, frogs, and other animals in order to find out what behaviors they could then perform. The animals were still able to carry on involuntary actions, such as reflexes and bodily processes, but they could neither learn nor remember. From these and other

[1]*Neuron* (nū′rŏn). [2]*Axon* (ăk′sŏn).
[3]*Dendrite* (dĕn′drīt).
[4]*Autonomic* (ô tō nŏm′ĭk).

[5]*Ganglia* (găng′glĭ *ȧ*); singular, *ganglion** (găng′-glĭ ŭn).
[6]*Cerebrum* (sĕr′ē brŭm).
[7]*Cerebellum* (sĕr ē bĕl′ŭm).
[8]*Medulla oblongata* (mē dŭl′*ȧ* ŏb lŏng gā′t*ȧ*).
[9]*Cerebral cortex* (sĕr′ē brăl kôr′tĕks).
[10]*Convolution* (kŏn vō lū′shŭn).

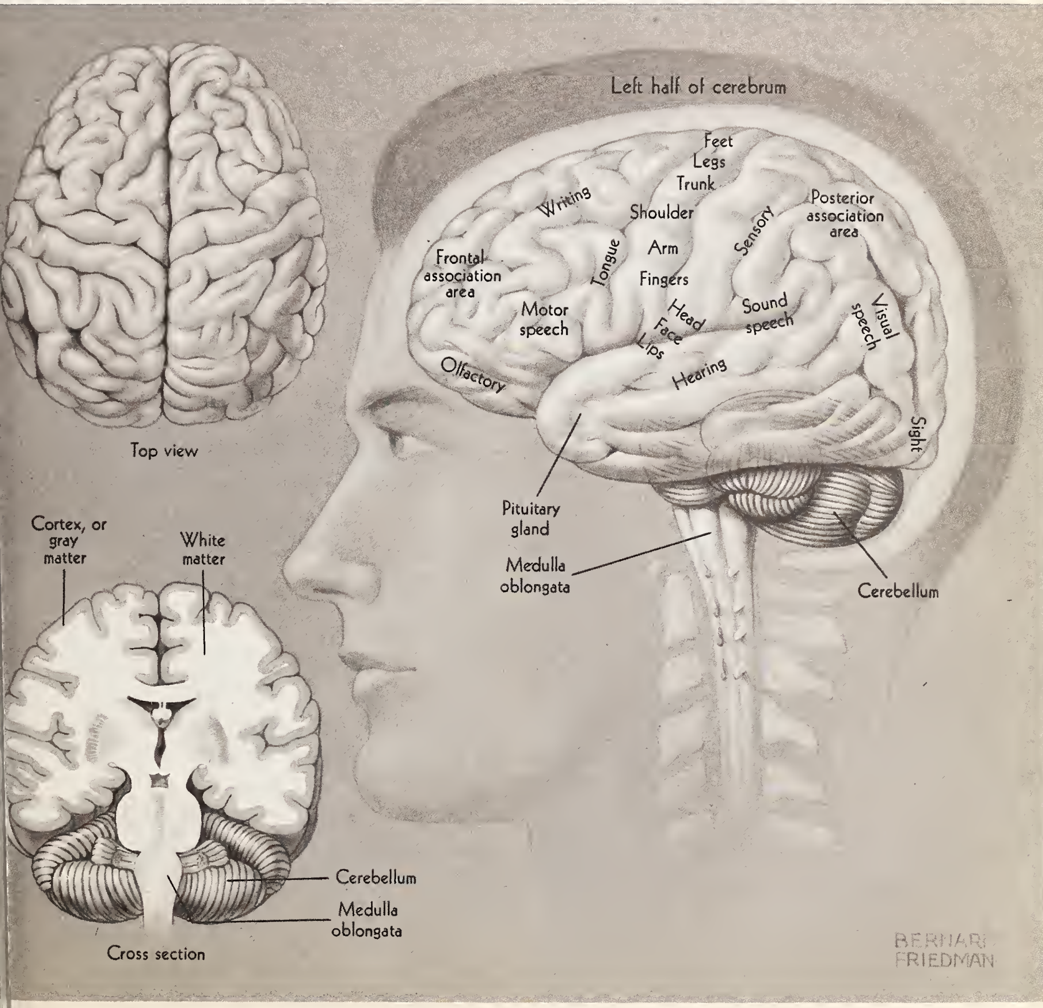
The human brain is superior to that of any other animal. The cerebrum makes up a larger part of the brain of man than the cerebrum does of the brain of any other animal. Should you expect the brain of an earthworm or an arthropod to be more or less complex than that of any of these animals? Can you state a principle in support of your answer?

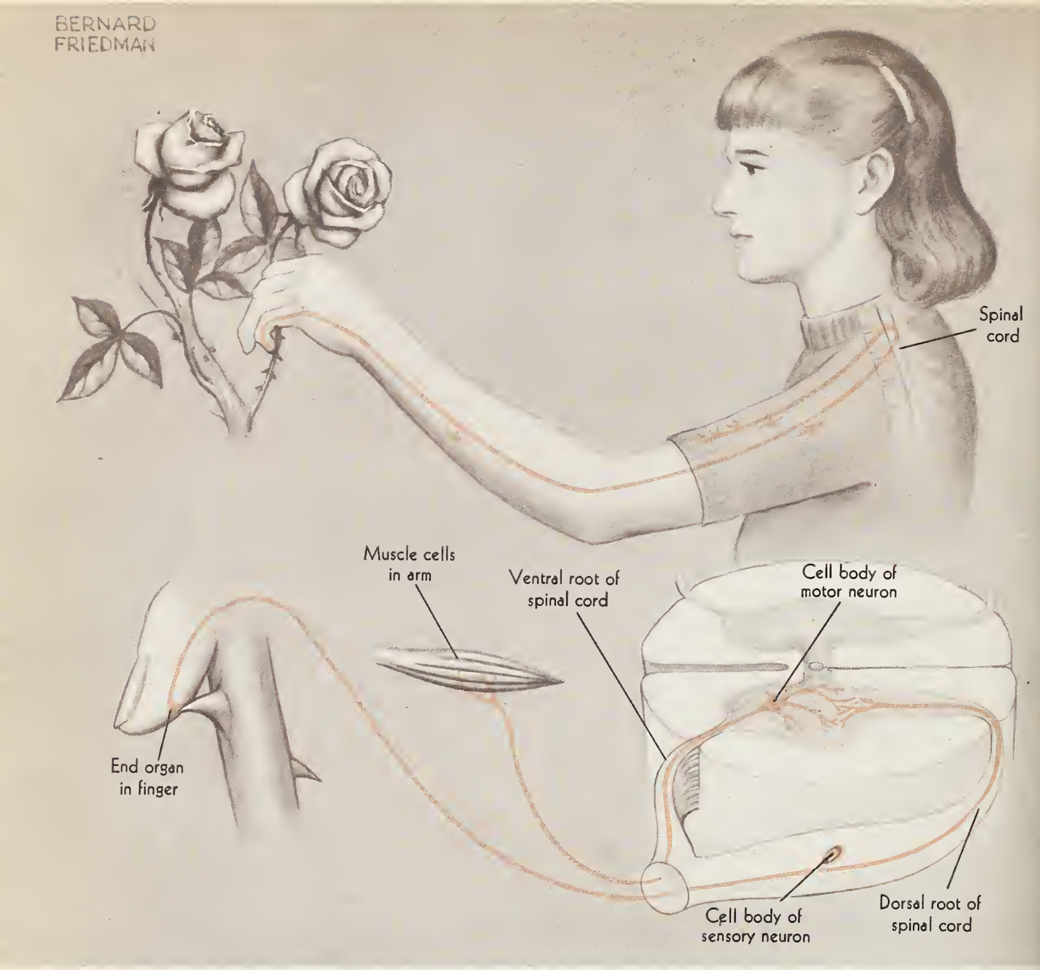
experiments scientists have concluded that the cerebrum is the center of voluntary action.

The white matter of the cerebrum is composed of the fibers of the nerves whose nuclei are in the cortex. The white matter derives its color from the protective coverings of the nerve fibers, which are white. These fibers serve to connect various areas of the cortex with one another, and with the cerebellum, the medulla oblongata, and the spinal cord.

It will be seen, from the statements about the gray matter and the white matter of the cerebrum in the preceding paragraphs, that the cerebrum co-ordinates, or keeps in har-

Three views of the human brain · Summary Question: Name the structure and state the function of each important division of the human brain





A reflex arc · All the sensory and motor nerves that together cause a reflex make up a reflex arc. How would you react, and why, if you did not know that a dog was near you and it suddenly thrust its cold nose into your hand?

mony, all the behaviors of the organism. Its cortex may be compared roughly to a switchboard operator, and its white matter to the wires over which the messages travel (illustration, p. 379).

The cerebellum is believed to control the muscles so that they act in harmony. If a person's cerebellum is injured, his movements become jerky and uneven. If he reaches for an object, his hand goes toward it, misses, and fumbles around it before he is finally able to pick it up. His gait becomes unsteady and jerky.

Many experiments with animals from which the cerebellums had been removed revealed that without this organ the animals

were unable to walk, fly, or even stand because they could not maintain their balance.

The medulla oblongata is the lowest part of the brain. It appears to be a sort of bulblike end of the spinal cord. Yet it is inside the skull instead of inside the backbone, or spinal column, as the spinal cord is. The medulla controls many of the involuntary actions involved in the bodily processes, including respiration, blood circulation, swallowing, and the formation of saliva. An injury to the medulla nearly always results in immediate death.

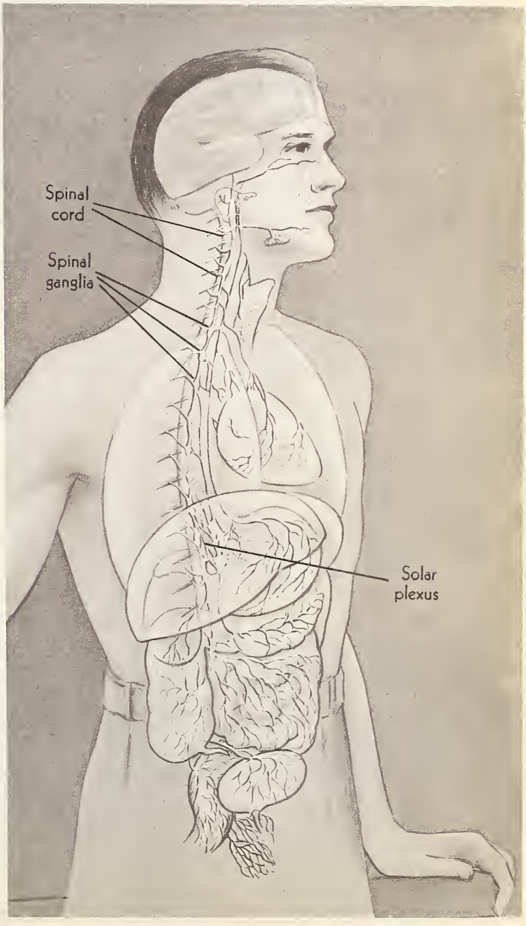
The spinal cord. The spinal cord carries impulses to and from various parts of the body and the brain. Also, it controls many reflexes.

In man thirty-one pairs of nerves connect the spinal cord with various parts of the body. Each nerve branches off from one side of the spinal cord in two strands, or roots (dorsal and ventral; illustration, p. 380). The two roots on each side join together and pass out between two adjoining vertebrae. Many neurons that make up each of these large nerves carry impulses from the sensory organs to the spinal cord, and others carry impulses from the spinal cord to muscles and glands.

Reflex arc. The following example indicates how the spinal cord controls a reflex action: Suppose you stick your finger with a thorn. You jerk your finger away even before you feel the pain. The impulse caused by the injury to the nerve endings of the finger travels along on several neurons in a nerve to the spinal cord. There it is immediately switched to the neurons that will cause the muscles in your arm to pull your finger from the thorn. Some of the impulse is carried also by other nerves (not shown in the illustration) up the spinal cord to the brain. There various impulses are interpreted and coordinated so that you become conscious of pain and also so that impulses from the brain will control your further reaction to the injury in your finger.

2. The autonomic nervous system. The pairs of ganglia on each side and somewhat in

The autonomic nervous system · The central nervous system and the autonomic system are connected to form one complex system. Thus voluntary and conscious reactions are connected with the involuntary and unconscious ones. How many of the organs shown here, that are under the control of the autonomic system, can you name (see illustrations, pp. 234 and 238)?



front of the spinal column are the chief centers of the autonomic system. There are, however, many other scattered ganglia which also belong to this part of the nervous system (illustration, p. 381). The autonomic nervous system is closely associated with the medulla oblongata in the control of many of the involuntary bodily processes, including digestion, circulation, and glandular action.

Knowledge not yet complete. [E]It should be kept in mind that though scientists have discovered what many of the functions of the various parts of the nervous system are, they have not yet discovered exactly *how* these functions are performed. They do know, however, that both chemistry and electricity are involved in all functions of nervous tissue.

BEHAVIOR AND GLANDULAR REACTIONS · The glandular system[1] is involved in many of our behaviors, especially those resulting from emotions. To illustrate, if you should see a car coming rapidly toward you when you were crossing the street, you would be ready at once to jump farther, run faster, or dodge more quickly than you ordinarily could. A moment later, when safe on the sidewalk, you might be so angry with the driver for putting you in danger as scarcely to be able to control your feelings. To illustrate further, recently when a dwelling burned, the owner, without help, carried out several boxes and pieces of furniture each of which ordinarily would have required two men to carry.

When one experiences fright, rage, or excitement, as in the examples just given, the adrenal glands[2] are stimulated to send extra quantities of the hormone adrenalin into the blood stream. This hormone stimulates the liver to release its stored glycogen, thus furnishing energy for unusual physical activity. Also, adrenalin increases the heart-beat and the breathing rate, and hence supplies all the cells with extra quantities of energy and oxygen. It causes the blood vessels in the digestive system to contract and those in the limbs to expand, with the result that more of the blood is available in the body parts that are likely to be used in running away, fighting, or performing unusual feats of strength and endurance.

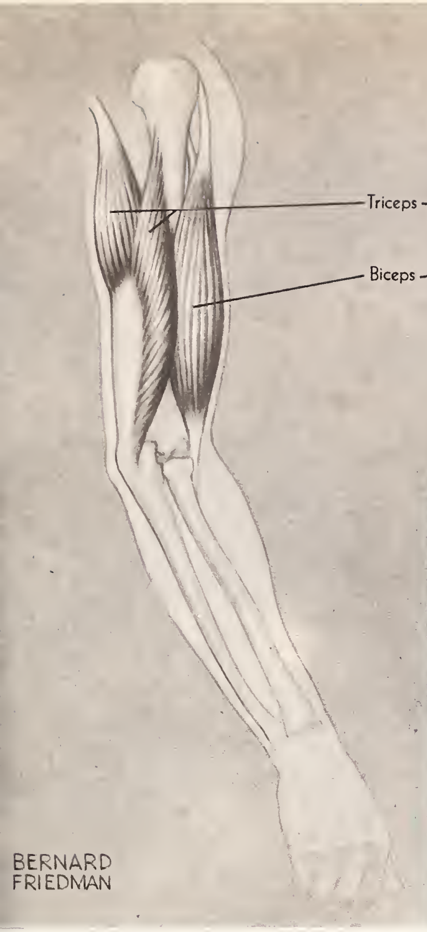
THE MUSCULAR SYSTEM · There is never an instant when all parts of one's body are still. Even while one is asleep, involuntary actions are being carried on. The heart is beating, and breathing, digestion, and metabolism are going on. If these involuntary actions were to cease, death would follow almost at once.

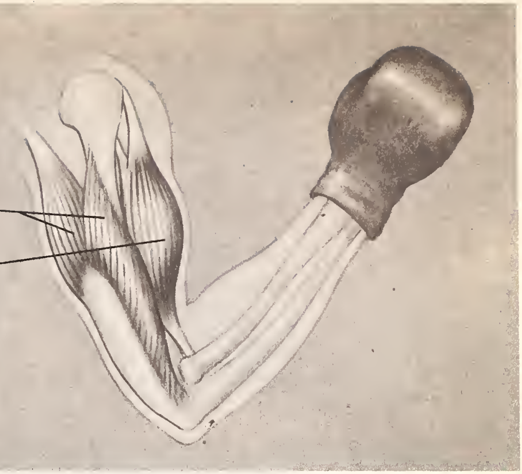
The muscular system is directly responsible for all bodily movements. There are two kinds of muscles, the voluntary muscles and the involuntary muscles. The voluntary muscles include the ones that we can move when we wish to. Therefore they are chiefly under the control of the central nervous system. The involuntary muscles work constantly without our being conscious that they do. They are under the control of the autonomic system.

1. Voluntary muscles. The voluntary muscles function chiefly in moving parts of the body, such as arms and legs. "Red" meat is voluntary-muscle tissue. If you secure from the butcher a section of the leg of a meat animal, cut above and below the knee joint, you can readily observe several characteristics of voluntary muscles. You will note that these particular ones are attached to the bones by tendons.[3]* Tendons are tough, fibrous cords or bands of tissue. Not all voluntary muscles are thus attached. Some are joined directly to the bones. Others, the circular

[1]Pages 289–293. [2]Page 292.

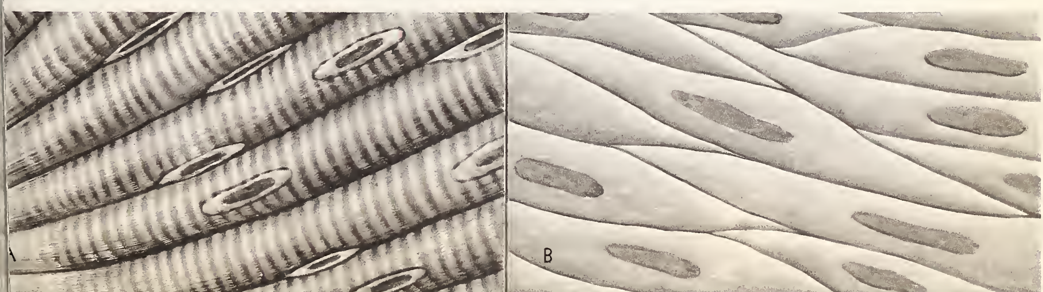
[3]*Tendon* (tĕn'dŭn).

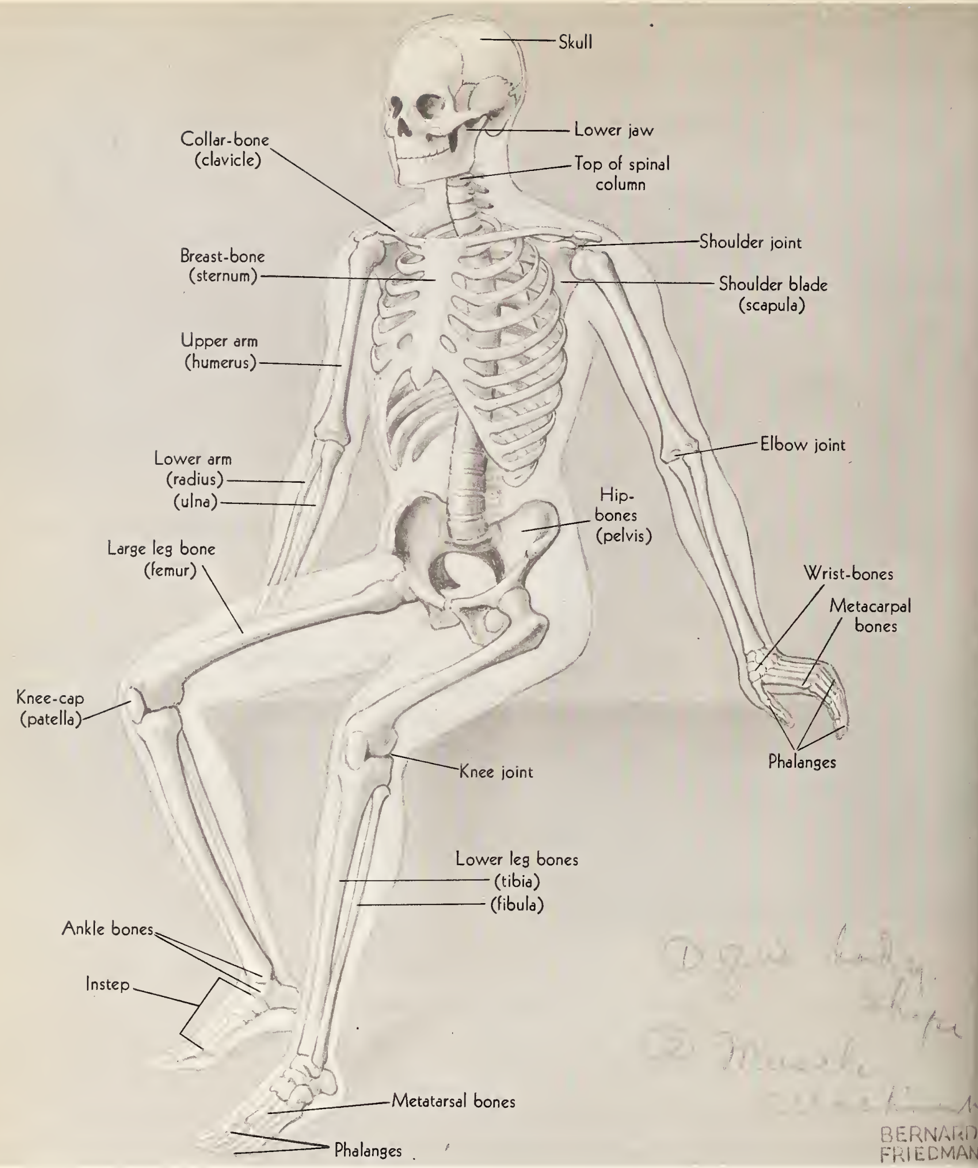




How muscles are attached and how they produce movements · A movement is produced by certain muscles, and the opposite movement is produced by others. For example, you grasp a stick by contracting certain muscles, and you loosen your fingers by relaxing these muscles and contracting certain others. The muscles that produce a certain movement and the muscles that produce the opposite movement are together known as antagonistic muscles because each counteracts the other. In a few instances a baseball-pitcher has broken his arm when he has thrown the ball. Can you explain how this could happen?

A, voluntary-muscle tissue (striped muscle); *B*, involuntary-muscle tissue (smooth muscle). In what ways do these differ?





An endoskeleton such as this serves (1) to protect vital organs (brain, heart, lungs, spinal cord, etc.), (2) to support the various structures, and (3) to provide attachments for the muscles, thus making most movements possible. Can you identify the different types of joints here? Make up some questions about this illustration and the text material relating to it—for example, "What advantages are there in having many short bones in the hand?"

ones, such as those around the eyes and the mouth, are attached to other muscles.

You will note that the muscles on the animal's leg consist of long, cord-like strands. These strands are made up of fibers composed of cells, which are, in some cases, only about four thousandths of an inch thick. When examined under a microscope, they appear to have alternate light and dark stripes across them. For this reason the voluntary muscles are called striped (striated[1]) muscles (illustration *A*, p. 383).

2. Involuntary muscles. The involuntary muscles are located chiefly in the internal organs, as in the walls of the heart, in other parts of the circulatory system, and in the walls of the alimentary canal. With a few exceptions, as certain heart muscles, these muscles are not striped, and for that reason they are called smooth muscles (illustration *B*, p. 383).

Muscles contract, or become somewhat shorter, when properly stimulated by a nerve impulse. When they relax, or become slack, they resume their former length. Muscles produce action by contracting (illustration, p. 383). The amount of force that a muscle can exert when it contracts depends on its condition. For example, a muscle that is in good condition from constant exercise can lift more than twice as much weight as the same muscle could lift if it were in poor condition from lack of exercise.

THE RELATION OF JOINTS TO MOVEMENTS · The movements of arms, legs, and most other parts of the body would not be possible were it not for the joints of the skeleton (illustration, p. 384). These joints may be classed as (1) immovable, that is, not movable; (2) slightly movable; and (3) freely movable.

1. The flat, plate-like bones of the skull have "saw-tooth" edges that fit together closely. These joints (sutures)[2] are considered immovable, although they can move slightly if enough pressure is applied.

2. Each vertebra is separated from the next by a thin pad of cartilage. Each joint of the spinal column, therefore, is only slightly movable. Yet the total result of moving all these joints is a large movement.

3. The bones of the arms and legs and their parts are held together at the joints by tough cords of connective tissue, called ligaments.*[3] Such joints are freely movable. They are of three types: (*a*) the hinge joints, such as those in the knees and fingers, which permit free movement in only two directions; (*b*) the pivot joints, such as those in the elbows, which make possible a circular motion of the arm, as when turning a faucet handle; and (*c*) the ball-and-socket joints, of the shoulders and hips, which permit movement in nearly every direction.

Movements of the parts of the body are made easier by the smooth, moist surfaces of the slightly movable and freely movable joints.

COMPLEXITY OF NERVE STRUCTURES AND COMPLEXITY OF BEHAVIORS · No plant has either nerves or muscles. Hence the reactions of all plants are slow and relatively simple.

[E]Most of the invertebrates and all the vertebrates have nervous systems that make tropisms, reflexes, and instinctive and other involuntary actions possible (illustration, p. 387). But only man and perhaps some of the other highest mammals have, in addition to such primitive nervous systems, brain structures that permit voluntary behaviors.

In the invertebrates with the simplest brains, the brain is scarcely more than a ganglion. Such was the case also with the giant

[1]*Striated* (strī'āt ĕd).

[2]*Suture* (sū'tūr).

[3]*Ligament* (lĭg'ȧ mĕnt).

reptiles which lived millions of years ago (illustrations, pp. 466 and 468). They had brains not much larger than your fist. The behaviors of all animals with such primitive brains are chiefly reflexes, carried out through the spinal cord.

In the lower vertebrates the spinal cord has a much greater weight and volume than the brain. In the mammals, however, the brain has a greater volume and weight than the spinal cord. Even in the lower mammals the brain weighs from two to four times as much as the spinal cord. In the apes it weighs fifteen times as much. In man the brain is more than fifty times as heavy as the spinal cord.

The large and complex brains of the higher vertebrates make possible types of behavior of which lower animals are not capable. The higher vertebrate is more able to delay a response and to choose one response from several possible ones.

[E]The greatest difference between the nervous system of man and that of even the other mammals is in his cerebrum. Man can perform an endless variety of voluntary behaviors which no other animals can, because his cerebrum is so much more complex than theirs. Not only can he reason and think, but also he can plan his future behaviors. All other animals, with the possible exception of a few of the higher mammals and these to only a limited extent, must meet each situation as best they can at the time when it arises.

2. How Do the Various Sense Organs Function?

There is no living thing that is not sensitive (irritable) to some factors or conditions in its environment. Sense organs have developed in all but the simplest animals. Animals vary considerably with respect to the kinds of sense organs that they possess. They vary also with respect to how complex and keen their sense organs are.

What an animal is able to experience depends on its special sense organs. For example, without eyes and ears we should have no way of knowing that such things as sights and sounds exist. There can be no doubt that our environment provides some kinds of stimuli to which we do not react, because our nervous system cannot receive, interpret, and respond to them. Some animals may be equipped to react to such stimuli. For example, recent observations of homing pigeons and experiments in which radar beams were directed at migrating ducks indicate that these birds are able to sense two kinds of stimuli which human beings cannot receive. These stimuli are differences in the earth's magnetism at different places and differences in the speeds with which various spots on the earth move as the earth turns on its axis. The ability of the pigeons to find their way back home and that of the ducks to keep a true course during migratory flights may result from their reactions to these stimuli.

Most biologists agree that in some animals certain senses are keener than the same senses in us. Eagles, hawks, and some other birds of prey are believed to have "telescopic vision," that is, eyesight so keen that they can see their prey while flying high in the air. If, however, we were flying in an airplane at the same height, we should not be able to discern small objects on the ground. Cats and owls can see far better at night than we can. Wolves, coyotes, and other predatory animals can follow the trail of a deer while running

at nearly full speed, by detecting the odor left by the deer's feet on the ground.

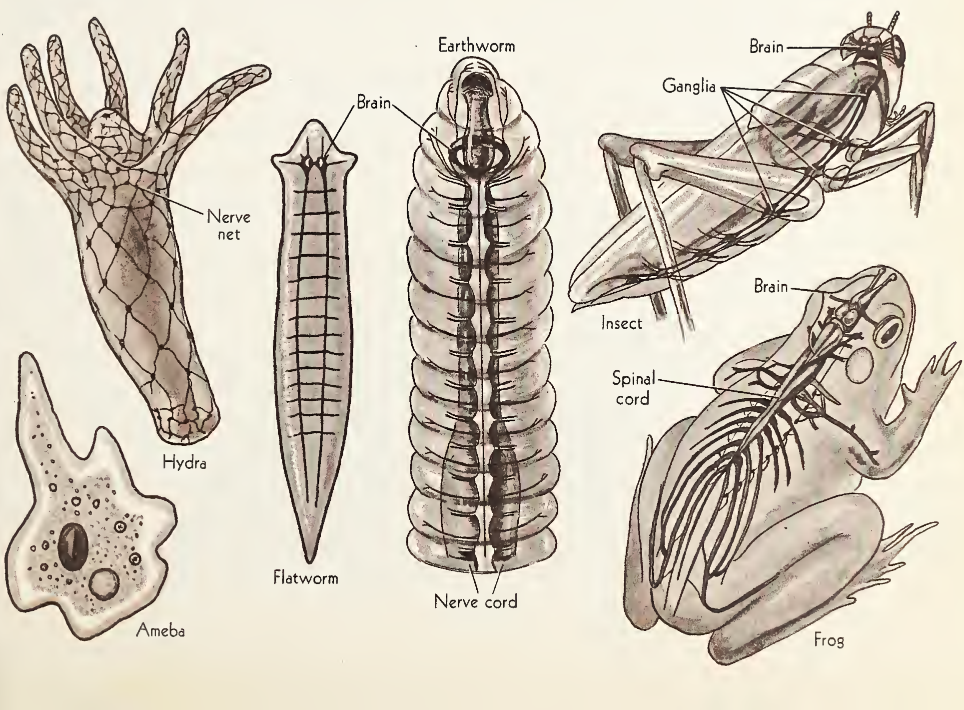
In contrast with these examples, some of our senses are keener than the same senses possessed by some other animals. For example, if you were to try to scare away a rattlesnake by merely shouting at it, you would not succeed. A rattlesnake senses and can probably hear sounds that come to it through the ground, but not those that reach it through the air. Chickens and other birds are unable to sense many colors that we distinguish clearly.

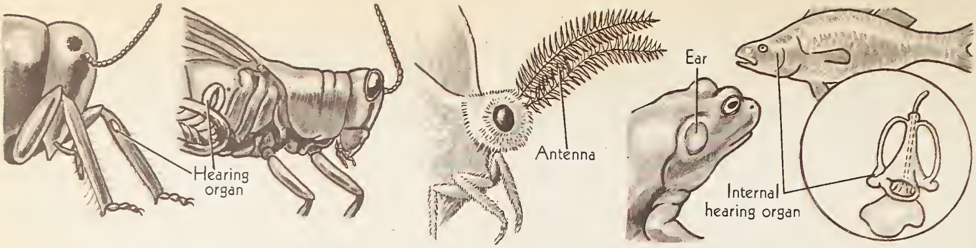
ORGANS SENSITIVE TO VIBRATIONS OF OBJECTS · A vibrating object is one that is moving back and forth. Each complete back-and-forth motion is one vibration. Vibrations cause waves that travel through air, water, and solids. Some plants and nearly all animals are sensitive to vibrations. Certain tropical trees in the South Pacific islands were affected by the jarring caused by the explosions of shells during the Second World War. Their branches drooped and did not regain their normal positions for several days after the explosions had ceased.

Most water animals respond when a jar causes vibrations to pass through the water. If you tap a pan of water containing some mosquito larvae, or "wigglers," the vibrations produced by the tapping are transmitted, or

All living things can respond to stimuli, but no plant and no animal simpler than Hydra has a special nervous system. Can you select the word of each pair that will make the following statement of a principle correct?

In general, the (*higher* · *lower*) an (*animal* · *plant*) is in the scale of life, the (*more* · *less*) complex its nervous system is





Hearing organs of various animals · Can you invent an experiment by which you could find out which of two dogs or cats possesses the greater range of hearing? Before you do so, study the steps on page 570

sent, through the water. These vibrations will cause the larvae to jerk downward from the surface, where they have come to breathe.

An excited soldier termite (white ant) will beat its head against the walls of the nest, thus jarring the ground and causing it to vibrate. Termites are sensitive to vibrations of a surface which their feet are touching. Hence all the termites in the nest become excited by the vibrations caused by the soldier. There is no evidence, however, that the soldier termite beats its head upon the walls of the nest *in order* to send definite messages to the others in the nest.

The sense of hearing · Some, but not all, vibrations are sensed as sounds by animals that possess organs of hearing. Only vertebrates and some of the arthropods have such organs. Probably most invertebrates below the arthropods in the scale of life[1] have sensory nerves that receive stimuli caused by vibrations. These nerves, however, are believed to be more closely related to the sense of touch than to that of hearing.

Many insects have organs on their legs, their abdomens, or in their antennae that are believed to enable them to hear some sounds (illustration above). Probably all or nearly all vertebrates have ears, more or less well developed, that enable them to hear some sounds. Like the rattlesnake, however, many of them can hear sounds only when the vibrations come to them through the ground. Others can hear sounds only when the vibrations come through water.

Pitch and hearing · During the Second World War dogs were used extensively as watchmen to protect manufacturing plants making war materials. The dogs roamed around the buildings and yards at night, and, because of their keen senses, were much more effective in detecting the presence of anybody who might break into the plant than human watchmen would have been. The dogs were controlled by signals which their keeper blew on a "silent" whistle. No person could hear these signals, though the dogs heard them clearly. The explanation is that different kinds of animals, as well as different individuals of the same kind, can hear different ranges of sounds.

[P]The more rapidly an object vibrates, the higher is the pitch of the sound that it produces. Most people cannot hear the sound made by anything that is vibrating more rapidly than twenty thousand times per second. But most dogs can. The whistle used with the dogs in the war plants probably vibrated as often as thirty thousand times per

[1]Page 512.

second. Hence its note was too high for the men to hear, but not for the dogs. If, however, the whistle had made only twenty-seven vibrations per second and hence had produced a tone as low as that produced by the lowest key on a piano, the dogs' keeper and anybody else near by could probably have heard it, but the dogs could not have.

A pigeon can hear the middle note on a piano, but a canary cannot. Neither of these birds can hear the shrillest sounds that we can hear. Practically all the sounds that a bat makes are above the range of our hearing. Rats can hear shriller sounds than cats, and cats can hear higher notes than dogs.

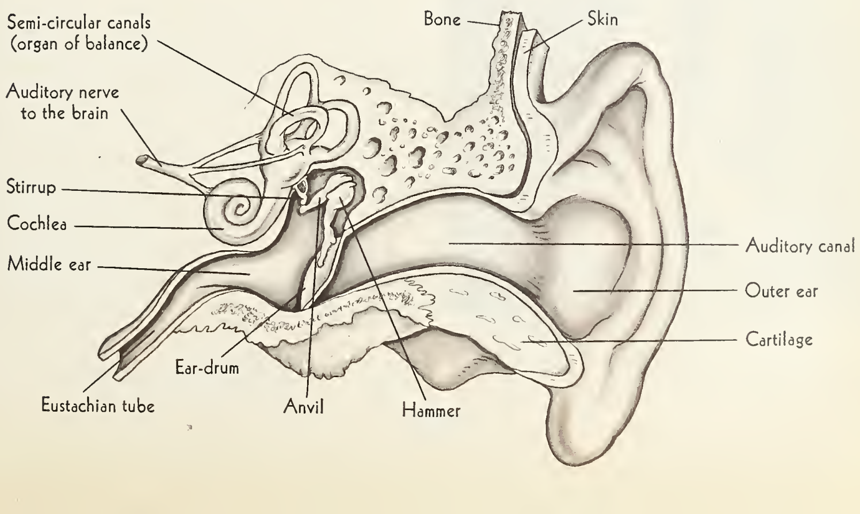
HOW THE HUMAN EAR FUNCTIONS · **As an organ of hearing.** Have you ever been listening to the radio when something on the other side of the room began to rattle? Perhaps it was a picture frame or a vase. The vibration of this object was caused by the sound waves passing from the radio in all directions through the air. A somewhat similar action takes place inside the ear when sound waves reach it.

Sound waves striking the outer ear are directed through the auditory canal to the ear-drum much as though they were running through a funnel (illustration below). The sound waves cause the ear-drum to vibrate, just as those from the radio caused the object to vibrate as described in the preceding paragraph. These vibrations then pass through three small bones in the middle ear to the inner ear (cochlea[1]). The vibrations produce corresponding movements in the fluid which the inner ear contains. Sensory neurons in the walls of the inner ear receive these impulses. The neurons are grouped together in a single nerve, called the auditory nerve. This carries the impulses to the auditory area of the brain. The brain interprets the sensations as sounds.

As an organ of balance. Most animals are able to sense when their bodies are not in their normal positions. For example, a turtle

[1]*Cochlea* (kŏk'lē *ȧ*).

Topic for Individual Study: There are estimated to be two thousand hair-like cilia in the inner ear. What is their function?



Ford, from Black Star

What organs and what senses enable these people to keep in balance?

or a crab, when it is turned over on its back, will struggle vigorously to regain its feet. We have three senses that together enable us to keep in balance. Through practice from infancy we learn to use these senses automatically. (1) One is the sense of sight. Some people, when seated, can balance themselves on the two rear legs of a chair by fixing their eyes on some spot on the wall. But if they close their eyes, or if somebody passes between them and the wall so as to cut off their view of the spot, they will lose their balance at once. (2) Another is the "muscular" (kinesthetic[1]) sense. If you lean over, you can tell from the way your body feels that you are off balance. (3) The third and probably most important is an organ of balance in the inner ear. This organ is composed of three small tubes (the semicircular canals) (illustration, p. 389). Each is at right angles to the other two. Cilia extend from their walls into a fluid which the tubes contain. At the bases of these cilia are sensory nerves. Whenever the head is moved in any direction, the fluid causes the cilia to move. This movement produces sensations which we learn to interpret automatically as indicating whether or not we are right side up (illustration on this page).

CARE OF THE EARS · [E]One should never thrust a hairpin, a toothpick, a match-stick, or other object into the ear, because of the danger of injuring the canal or the ear-drum. One should not blow the nose violently and with the nostrils pinched when one has a cold. Doing so is likely to cause harm in two ways: (1) it may force germs through the tube (Eustachian tube[2]) that leads from the throat to the middle ear, and thus cause an

[1]*Kinesthetic* (kĭn ĕs thĕt′ĭk).
[2]*Eustachian* (ū stā′kĭ ăn).

infection of the middle ear, or (2) it may force enough air through the tube to injure the ear-drum. While the nose is being blown, the mouth should be kept open to decrease the pressure through the tube.

Whenever there is pain in or about the ears, or any evidence that one's sense of hearing is becoming less keen, an ear specialist should be consulted at once.

ORGANS SENSITIVE TO OTHER VIBRATIONS · No doubt you know that radio results from sending and receiving waves which travel through space. Only a certain band, or section, of such waves are radio waves. This band includes relatively long waves—those that vary in length from several miles to a few inches. Heat from the sun or from a fire travels in the form of another band of waves. These are shorter than radio waves. Light travels in the form of still another band of waves, and these are shorter than heat waves.

Thus radio waves, heat waves, and light waves are closely related. In fact, there is no difference between any of them and any other of these waves except their length.

The reactions of certain specialized nerves of animals to light waves result in the sense of sight. The reactions of other specialized nerves result in the sensation of warmth. Recent evidence strongly indicates that the reactions of still other specialized nerves to certain heat waves result in the sense of smell.

The sense of sight. Most animals are more or less sensitive to light. Only those, such as tapeworms and other animals, that live their whole lives in darkness are not.

Amebas and other protozoans have been observed to respond to light, though the observers have not been able to discover any part of their one-celled bodies that seems more sensitive to light stimuli than any other part. Some of the "border-line" organisms[1] and some metazoans, such as flatworms[2] and starfish, have eye-spots (illustration, p. 392). Eye-spots are too primitive to be regarded as eyes; yet they are definite structures that are sensitive to light. Earthworms have neither eye-spots nor eyes. They have, however, on the outside of their bodies, certain nerve cells that are sensitive to light. Many invertebrates have primitive organs of sight which enable them to detect light and shadow.

The sense of vision, in animals that have this sense, varies greatly. Some have only the ability to distinguish differences in the strength of light. Others are able to note also shape, size, color, motion, and perspective, or distance from the observer. The muscular sense involved in the sensations from the external eye muscles functions, along with vision, in enabling the higher mammals to judge distances.

With few exceptions, only animals high in the scale of life have eyes. Eyes are of three types: (1) simple eyes, (2) compound eyes, and (3) lens eyes, or camera eyes. These types will be described later. Some arthropods have only simple eyes, others have only compound eyes, and still others have both. Thus spiders have only simple eyes, usually three or four pairs of them, depending on the species of spider. Lobsters and most other crustaceans have only compound eyes. Grasshoppers, bees, and many other insects have two compound eyes and three simple ones.

Practically all vertebrates have camera eyes. A few mollusks, such as octopuses and cuttlefish, also have camera eyes, which, to a considerable extent, resemble those of the highest mammals.

[1]Page 564. [2]Page 519.

An ancient organ of sight. For several hundred years scientists have been puzzled about the functions of a certain organ in the heads of vertebrates. This is a yellowish body, about the size of a pea, located at the end of a short stalk between the two halves of the brain. In the seventeenth century Descartes,[1] a French wise man (philosopher), proposed the theory that in man this body is the seat of the mind.

This organ is the pineal body. It is now known to be one of the endocrine glands. Scientists do not yet know what its functions are, but they have learned some of its curious history. They have found evidence to indicate that at one time, in certain primitive vertebrates, there was at the end of the stalk, not a gland, but instead one or perhaps two imperfectly developed, extra eyes. This eye, or these eyes, peered dimly upward from the middle of the heads of these ancient creatures, which lived in the mud and which became extinct millions of years ago. Traces of a somewhat similar rudimentary third eye are found in the heads of many of the present-day amphibians and reptiles.

The simple eye. The simple eye may be considered to be a primitive form of the lens eye, or camera eye, such as man and other mammals have. The transparent, curving membrane that forms the front of it serves as a lens. This focuses the light on the light-sensitive nerves at the back. Impulses from these nerves travel on other nerves to the brain.

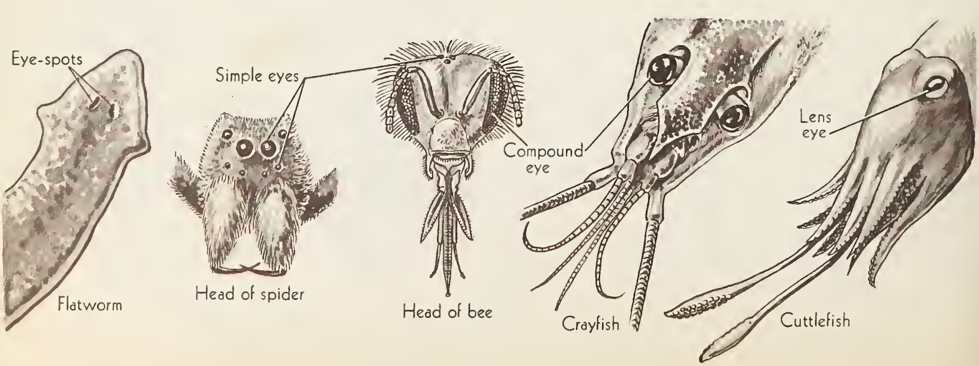
Simple eyes probably enable the animal possessing them to detect movement, to judge short distances, and perhaps also to distinguish large objects from small ones. Scientists do not yet know for certain, however, exactly what can be seen by animals with either simple eyes or compound eyes.

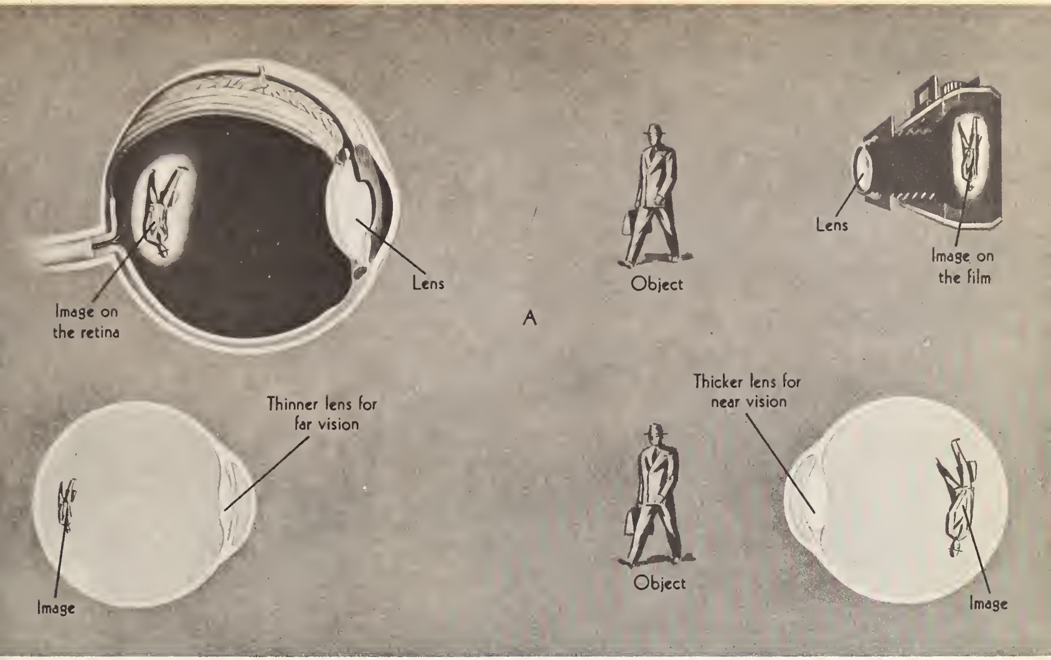
The compound eye. The compound eye may be thought of as a group of simple eyes, numbering from as few as about twenty in some arthropods to sometimes many thousands in others. Each eye produces independently an image of what is directly in front of it. As a result, all the images form a mosaic on a light-sensitive area, somewhat like a round spot of wall surfaced with tiles all having almost exactly the same design on them.

The compound eye is believed to be affected by changes in the strength of light and to function in detecting the movement of near-by objects. It probably does not permit

[1] *Descartes* (dā kärt′).

Types of organs of sight of invertebrates · This illustration shows an exception to the third principle, p. 405. What is the exception (see illustration p. 512)?





A, the vertebrate eye is much like a camera. *B*, how does the lens in the eye change in thickness as the object approaches or moves farther from the eye?[1]
Topic for Individual Study: The cause and correction of near-sightedness, far-sightedness, and astigmatism

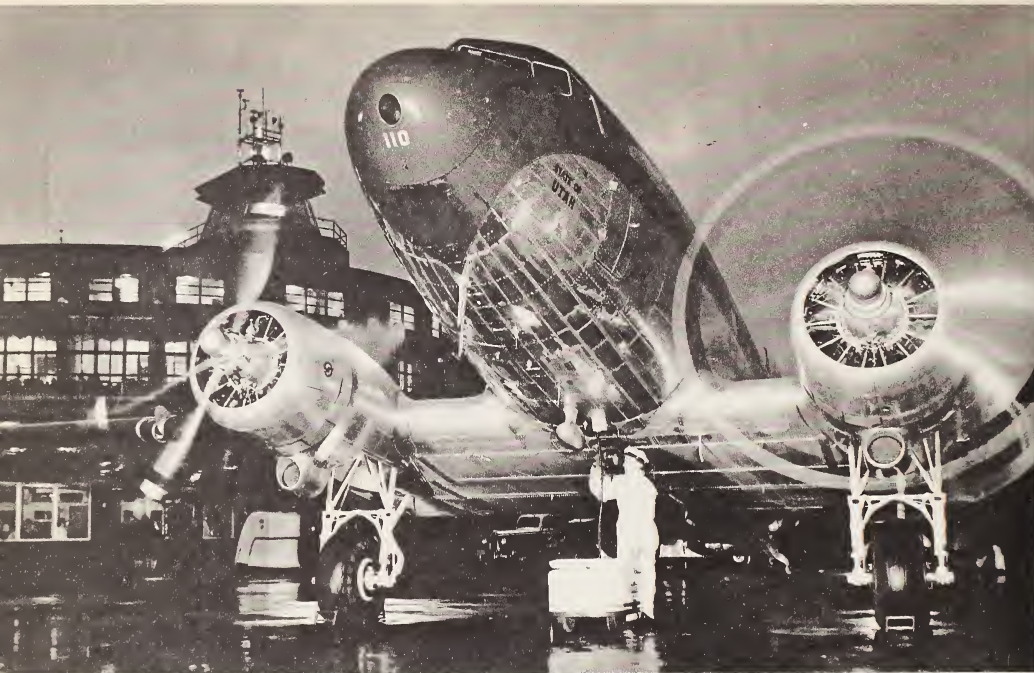
the animal possessing it to see much detail. Even the most farsighted insects are believed to be unable to detect even movements farther away than six or eight feet. The simple and compound eyes in insects that possess both are believed to supplement each other.

The lens, or camera, eye. Human eyes, like the eyes of most of the other chordates, are held in bony sockets in the skull. They are thus well protected except in front. There they are protected to a considerable extent by the eyelids.

The pupil serves as a "window" through which light passes through the lens (illustration above). Muscles in the iris automatically relax in dim light and thus enlarge the pupil, causing it to admit more light through the lens. In bright light they contract, reducing the size of the pupil and the amount of light that would otherwise enter.

The lens focuses an image upon the retina. This is a lining of light-sensitive nerve cells which covers the back of the inside of the eyeball. Impulses from these cells go through the optic nerve to the "vision" center in the brain. Muscles, acting automatically, contract to increase, or relax to decrease, the thickness of the lens in such a way that images of objects at varying distances from the eye are focused upon the retina (illustration *B*,

[1]No attempt is made here to show the exact path of the light from the objects to the images. You will learn later how and where images are located if you study physics.



United Air Lines

Three American scientists have reported that a night flier who smokes even one cigarette immediately before or during a flight suffers a loss of vision that may be dangerous. What bearing do you think these statements have upon smoking while driving a car at night?

p. 393). The actions of the muscles controlling the iris and the lens are reflexes.

CARE OF THE EYES · [E]Civilization brings many strains on the eyes. Early man's daily activities, like those of most animals except man today, ended when darkness came. Even the pioneers did not use their eyes in so many ways or for such a large part of their waking time as people now do. Today people are likely to read in dim, flickering, or glaring light. They read on trains and busses, where the printed page is constantly in motion. There can be no doubt that such practices and other common ones cause eye-strain, which may result in permanent injury.

It is a good practice for everybody to have his eyes examined by an eye specialist at least every two or three years. When this is done, not only are glasses prescribed when they are needed, but also sometimes serious eye diseases are detected and cured in their early stages.

Reading, writing, or doing other things which require the focusing of the eyes on objects close by for a long period puts the muscles which control the shape of the lens under constant strain. For this reason, while doing "close work," you should look occasionally at some distant object. By so doing you give the muscles a chance to relax, and hence briefly to rest.

Dark glasses are of value when the sunshine is too bright or when there is a glare from reflected light. Cheap dark glasses, however, are likely to do more harm than good. Instead of having ground lenses, they usually have molded ones. The glass of a molded lens often has flaws in it, or the lens is likely to have "wavy" surfaces. Hence such lenses may change the direction of the light passing through them so much that it is impossible for the lens of the eye to form a clear image on the retina. Eye-strain results. Dark glasses should be secured only through an eye specialist, who will provide correctly shaped, polished lenses of high-quality glass.

It is important to keep the lenses of all glasses clean. To avoid scratching the lenses, polish them only with a soft cloth or with the special lens papers now available.

Cosmetics should be used with care around the eyes. Some of them contain substances harmful to the eyes. Manufacturers are compelled by the Federal Food, Drug, and Cosmetic Act of 1938 to put on the labels of their products warnings of possible dangers from using them.

ORGANS SENSITIVE TO PAIN AND TO CHANGES OF PRESSURE AND TEMPERATURE · Have you ever thought about how much the survival of at least the higher animals depends on their being able to feel pain? A dog, for example, limps along on three legs and holds up the injured fourth until it heals. A horse soon learns not to try to go through a barbed-wire fence. Without the sense of pain to start the right protective responses when the animals are being injured, few would be likely to become old enough to produce young. Consequently, without the sense of pain, most kinds of animals would in a short time become extinct.

It is not certain whether the metazoans without well-developed nervous systems feel actual pain or merely some sensation closely related to it. It is known, however, that practically all animals and a few plants are sensitive to contact, or pressure.

Plants and the lower animals are sensitive to temperature changes. Usually, however, their responses can be readily observed only when the changes are relatively great. As would be expected, the chordates[1] and also the higher invertebrates[2] are more sensitive to slight changes of temperature than the plants and the simpler animals. The nerve endings that respond to heat waves from the sun or from a fire are the same ones that are stimulated when a warm object touches them.

Snakes and lizards are more active in warm weather than in cold. The snowy tree cricket "fiddles" more rapidly when the temperature is high than when it is low. Ants react strongly to changes of temperature. One scientist found that they travel about fifty-two feet per hour when the temperature is 50° F and seven hundred and eighty feet per hour when the temperature is 100° F. By timing the ants he was able to estimate the temperature within one degree, or by noting the temperature he could estimate, with an error of not more than 5 per cent, the speed at which the ants were traveling.

In the higher vertebrates the specialized nerves that are sensitive to pain, contact, heat, and cold are closely associated. The nerve endings, or "spots," of these different nerves are so close together that a stimulus, especially a strong one, will often give more than one of these sensations. For example, when you put your finger against something hot, you are conscious not only of the sensation of pressure, but also of sensations of heat and pain.

[1]Pages 337–350. [2]Pages 512–532.

THE USE OF ANESTHETICS

NOT MUCH MORE than a century ago the operating rooms of hospitals were places of dread and horror. No anesthetics were used. Consequently many patients preferred to die from disease or injury, rather than endure the agony of an operation.

Some means of reducing pain were known in ancient times. Homer, Herodotus, and Pliny all mention the use of narcotic drugs which make people insensible (unconscious). Early Spanish explorers found that the natives of South America chewed the leaves of the coco tree, from which cocaine is now derived, to lessen fatigue on long marches. As early as the third century A.D. a Chinese physician, Hoa-tho, used a preparation of hemp to make patients unconscious while undergoing surgical operations.

In the thirteenth century Hugo de Lucca, an Italian physician, used mandragora extensively as an anesthetic, and in 1782 Augustus, the king of Poland, had a limb amputated under an anesthetic. None of the early anesthetics, however, was very successful. Hence few surgeons attempted to use anesthetics until the nineteenth century.

In 1842 Dr. Crawford W. Long, of Jefferson, Georgia, successfully used ether as an anesthetic in an operation on the neck on a patient. Without knowing of Dr. Long's work, in December, 1844, Dr. Horace Wells, a dentist of Hartford, Connecticut, had his own tooth extracted while he was insensible as a result of having inhaled laughing gas (nitrous oxide). In September, 1846, Dr. W. T. G. Morton, a dentist of Boston, proved the pain-killing qualities of ether as a general anesthetic by having his own teeth extracted while under its influence. The next month Dr. Morton successfully administered ether to a patient who had to undergo a leg amputation.

The news of Dr. Morton's use of ether reached England on December 17, 1846. Two days later a London dentist used ether successfully, and on December 21 Robert Liston, an eminent Scottish surgeon, began the practice of administering it. In a short time nearly all the European surgeons had adopted this method of relieving patients of pain and shock.

Certain modern methods of anesthesia, such as the injection of an anesthetic into the spine or other nerve center, allow the patient to remain conscious during an operation and yet feel no pain.

The Wesley Memorial Hospital, Chicago, is one of the finest hospitals in the world.
Topic for Individual Study: The history of hospitals

Each kind of nerve ending, when stimulated, gives rise to only one kind of sensation. For example, if you press a pin point lightly on a pressure spot, you get only a sensation of pressure, or contact. But if you apply the pin point in the same manner to a pain spot, you have a feeling of pain. If the pin is warm, it stimulates the heat spots. If it is cold, it stimulates the cold spots.

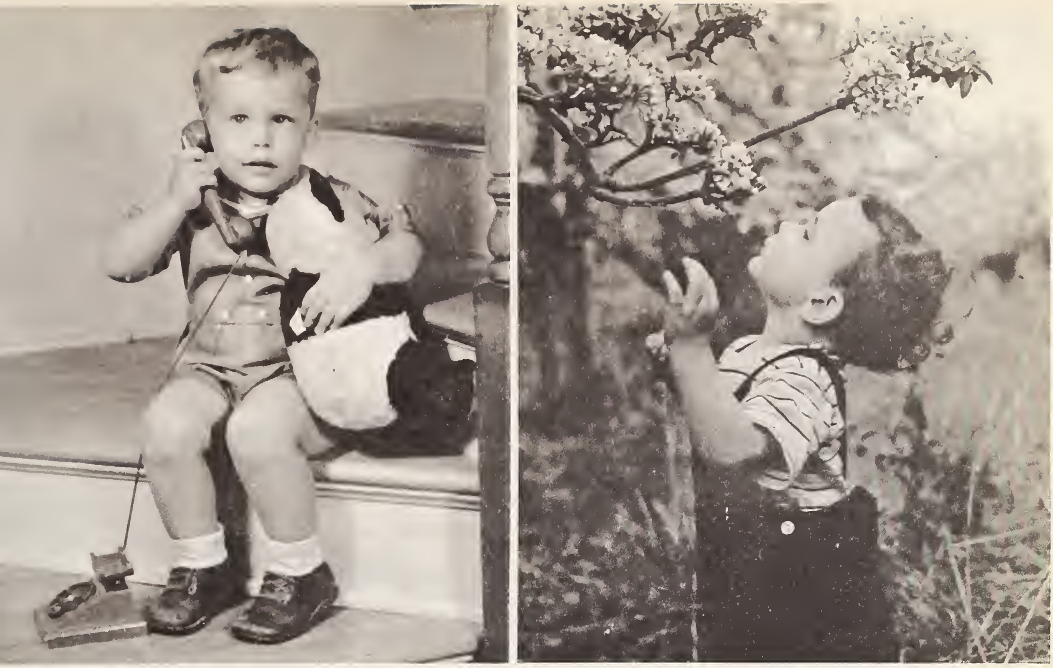
Sensitivity to pain and sensitivity to changes in temperature and pressure are not limited to special parts of the body or to special organs, as are sensitivity to sound and sensitivity to light. Practically the entire exterior of the body is capable of having some or all of these four sensations.

Having the specialized nerve endings, or spots, scattered over the entire body is an important aid in survival, because these nerve endings give warning of extremes of heat or pressure that are great enough to destroy body tissues. If the spots were grouped in one part of the body, in a single sense organ, another part could even be destroyed without the organism's sensing the fact.

All areas of the skin are not equally sensitive to heat, cold, pain, and pressure (illustration below). The back of your neck is less

Which of the four kinds of specialized nerve endings which together make up the sense of touch do you think are being stimulated here? Usually our sensations are not of just one kind, but are a combination of the sensations received from several different sense organs stimulated at the same time. Explain

Titcomb, from Black Star



F. W. Ouradnik (left); Howard E. Jones (right)

What senses besides those obviously suggested are being stimulated in each picture? Which of the senses discussed in this section are not?

sensitive to pressure than your finger tips. Few other parts of the body are so sensitive to pain as are the canals of the ears. The reason for variations in sensitivity, such as these, is that the different kinds of nerve endings are not evenly distributed throughout the areas of the skin.

The internal organs are less well supplied with the four kinds of sensory nerve endings than is the exterior of the body. Some of our internal organs have no pain nerves. The so-called muscular (kinesthetic) sense, which enables us to know, from the feeling, what positions our arms, legs, and other body parts are in,[1] is probably due to nerves sensitive to pressure, within the muscles.

The sense of smell. Evidence such as the following leads scientists to conclude that some insects have organs of smell on their antennae: Even though an ant has its eyes covered with black wax, it can follow trails, find its nest, and carry on life about as usual. Carrion beetles can normally locate food at considerable distances from them. But if their antennae are cut off, they cannot find such food, though it is only a few feet away.

In man and the other higher vertebrates the organs of smell are located in a small area in the back of each nostril.

ORGANS SENSITIVE TO CHEMICAL ACTION · **The sense of taste.** Taste is a chemical sense. It results from chemical reactions that take place on special sensory nerve endings. Until late in 1947 the belief was general among scientists that smell also was a chemical

[1] Page 390.

Evanston Township High School, Illinois

What statements in the text explain why athletic coaches demand that the members of their teams drink no alcohol?

sense, instead of being, as is now believed, the responses of specialized nerves to certain heat waves.

Invertebrate animals which are as low in the scale of life as earthworms are believed to have a sense of taste because experiments have shown that they prefer certain foods to others. There is much evidence to indicate that this sense is possessed by many arthropods and perhaps by most of the vertebrates. If you touch the foot of a red-admiral butterfly with a drop of sugared water, it will extend its proboscis[1] as though it were going to drink nectar from a flower. Hence the butterfly's taste organs are believed to be on its feet.

A hungry catfish becomes excited if an earthworm is placed in the water at some distance from it. If the worm is brought near the catfish in such a way that the fish cannot see it, the fish will nevertheless immediately turn and snap it up. This behavior leads some scientists to infer that the catfish finds its food by taste organs which are located in its skin.

In man the sensory organs of taste, known as taste buds, are distributed over different areas of the tongue, mouth, and throat, though chiefly of the tongue. There are four kinds of taste buds. They give us the sensations which we know as salty, sweet, bitter, and sour. Two or more kinds can be stimulated at the same time. The result is a blending of the sensations. Many of the different flavors of foods are due to such blending.

Since the passages from the nose open into

[1]*Proboscis* (prō bŏs′ĭs): the long, flexible snout of such an animal as an elephant or a tapir; or the suck ing tube of an insect.

the back of the mouth, we both taste and smell most of the foods we eat. Therefore what we believe to be flavors are often chiefly odors or are a blend of flavors and odors. Also, part of the flavor of food is due to added sensations of touch and of heat or cold. Thus hot coffee has a different flavor from cold coffee, and a dry soda cracker has a different flavor from a stale, damp one, because of the difference in the sensory organs stimulated.

The use of tobacco tends to injure the organs of taste and smell and consequently to reduce the effects of the flavors and odors of food.

DRUGS AND ALCOHOL · The alcohol in beer, wine, and other liquors is quickly absorbed into the blood stream and hence is quickly circulated throughout the body. It immediately and strongly affects the nerves. Because the brain is more abundantly supplied with blood vessels than are other parts of the body, the higher nerve centers are affected first. Consequently the judgment is impaired, and the controls of the emotions and the behavior are weakened. Hence, under the influence of alcohol, people are more likely to do foolish and reckless things than they would if they were in complete control of their emotions and their higher thought processes (illustration on this page).

Other effects of alcohol that prevent normal behavior include these: (1) alcohol makes the reactions to stimuli slower; (2) it disturbs the co-ordination of nerves and muscles, that is, it prevents their working in harmony; (3) it disturbs the sense of balance; (4) it renders sensation less keen; and (5) it tends to make one drowsy.

Narcotics. When prescribed by competent physicians, several of the narcotic drugs are of great value, especially in relieving pain. They are, however, habit-forming; that is, the person who takes them may develop a craving for them that causes him to continue to take them. When taken thus, habitually, cocaine, heroin,[1] hashish,[2] morphine, or opium produces terrible effects. These effects result from the injury which such drugs do to the protoplasm, especially to the nerve tissue. The addict[3] loses, to a constantly increasing extent, the control of his thought processes, his emotions, and his muscular reactions. Sooner or later his ruin is complete.

[1]*Heroin* (hĕr′ō ĭn). [2]*Hashish* (hăsh′ēsh).
[3]*Addict* (ăd′ĭkt): a "habitual user," that is, one who cannot get along without the drug to which he is *addicted* (ă dĭk′tĕd).

This cartoon won the National Safety Council's award for "distinguished service to safety." Why do you think it was placed at this spot rather than on page 345 or elsewhere? Which of the effects of alcohol stated on this page apply to this illustration?

Armstrong, in the Spokane *Spokesman-Review*

Within recent years the use of the dangerous drug marijuana[1] has spread to an alarming extent throughout the United States. Marijuana is closely related to hashish, or Indian hemp, a drug which is used rather commonly by addicts in parts of Asia and Africa. Marijuana is put into candies and drinks, but more commonly into cigarettes, which are known as "Mary Warners" and "reefers."

Many boys and girls have formed the habit of smoking marijuana cigarettes, which, in some cases, were given or sold to them by peddlers near the school. Under the influence of marijuana the victim loses control of his judgment and emotions to the extent that he indulges in silly or abnormal behaviors. Sometimes the latter include the most serious crimes.

3. *How Does Man Supplement His Senses?*

From early times men have been using various methods for increasing their ability to detect stimuli. For example, in pioneer days Indian scouts placed their ears to the ground and thus were able to hear the vibrations made by the footfalls of horses long before the approach of the animals could be heard through the air.

Scouts in the Second World War used a similar method to detect movements of the enemy. They stuck the bayonets of their rifles into the ground, then placed their ears against the bayonet blades. Thus vibrations too weak to be caught by the ear when they were coming through the air were strong enough to be sensed readily when they were passing through the solid ground and the metal.

In recent years man has developed many devices to supplement his sense organs and thus to enable him to detect and react efficiently to many stimuli which his unaided sense organs could not receive. Such inventions have made it possible for him to live more successfully.

Books could be filled with detailed accounts of these inventions (illustration, p. 403). Space will permit only a few to be briefly described in this section.

SUPPLEMENTING THE SENSE OF HEARING · Many people become "hard of hearing" as they grow old. Others lose their sense of hearing through sickness or accident. There was a time when all deaf people were doomed to live in a world of silence. Many no longer are. A small device, or appliance, equipped with tiny radio tubes and attached to the ear, collects sound waves and amplifies them, or builds them up, until they are loud enough for the deaf person to hear them. They reach the inner ear in the normal manner, or, in some cases in which the middle ear is damaged, the vibrations are transmitted to the skull at a point just behind the ear. In the latter case they travel to the inner ear through the bones of the skull.

During the Second World War it was necessary to locate airplanes and submarines at great distances. Huge mechanical "ears" were invented to locate airplanes. These "ears" collected the sounds from a large area and amplified them. By this method planes could be heard and their directions of flight could be discovered long before they could be seen.[2]

Somewhat similar sound detectors were invented for use on war-ships. These devices were sensitive to sound waves traveling

[1]*Marijuana* (mä rē hwä′nä).

[2]Page 406, No. 2 (first column).

Two earlier devices for supplementing the sense organs · How many modern devices for supplementing the sense organs can you name in one minute?

through water from the propellers of ships. By using them the crews of submarines and destroyers were able to locate the positions of enemy ships so accurately that they were often able to torpedo them without ever seeing them.

The development of the telephone has made it possible for people separated by long distances to hear each other's voices. The invention and improvement of radio have done more than this. With it communication is possible with people at the south pole, in jungles, in airplanes, and almost anywhere else on the earth. When Abraham Lincoln spoke to the people of his day, only those within the sound of his voice could hear him. Today a President, a prime minister, or, in fact, any citizen can speak from his home to millions of people all over the world.

SUPPLEMENTING THE SENSE OF SIGHT · By means of radar, airplanes, ships, and other objects can be accurately located, through fog, smoke, and darkness.

With another recent invention it would be possible to detect the light given off by a single candle at a distance of three thousand miles. With still another, in which radio tubes are employed, two million different shades of color can be distinguished.

Through the use of X rays man is able to see the inside structure of almost anything that he wants to examine. All the metal parts that go into machines can be examined to locate imperfect parts that may cause failure in use. Some of the uses of the X ray in diagnosing and combating diseases are stated in another chapter.[1]

A flier no longer needs to see outside his cockpit in order to pilot a plane. By watching instruments on the panel in front of him and listening to radio signals, he can tell whether he is on the right course; whether there are planes above, below, in front of, or behind him and how far away they are; and whether he is approaching a landing field in such a way as to ensure a safe landing.

SUPPLEMENTING OTHER SENSES · Modern flying requires so many and such rapid changes of position and direction that the human organs of balance do not function effectively. Hence it would often be dif-

[1]Page 334.

ficult and sometimes impossible for a pilot to tell whether he was flying right side up or upside down if it were not for a recently developed appliance. This device, installed on the instrument panel, enables the pilot to tell at a glance whether his plane has rotated out of its normal position.

Another device, called the autopilot,[1] provides man with what may be considered almost a new sense. This instrument functions somewhat like a "sense of location" in enabling a pilot to go directly to a desired destination over strange territory. After the autopilot has been set for a particular course, if the plane is tipped in any way that might make it change its direction of flight, the instrument brings it back to the true course within a few seconds.

[1]*Autopilot* (ô'tō pī lŭt).

An electron microscope in use · Such a microscope can magnify some objects two hundred thousand times. **Topic for Individual Study:** Prepare a report on the electron microscope to be given in your biology class or your science club

Radio Corporation of America

In some industrial plants, as well as in mines, poisonous gases sometimes escape into the air; and unless they are removed at once by proper ventilation, they are injurious to the workers. A device using radio-type vacuum tubes has been developed that will "smell" a minute quantity of these gases in the air and automatically ventilate the building or the mine tunnel.

Sensitive gauges have been developed that "feel" depressions, or hollows, in a flat surface that are no more than one millionth of an inch deep. Without such gauges it would not have been possible to make the surface of the mirror of the huge telescope on Mt. Palomar, California, as smooth as it had to be. In order to serve its purpose, the mirror could have a maximum difference of not more than two millionths of an inch between the deepest depression and the highest elevation on its surface.

An appliance called a thermocouple[2] detects changes in temperature of one millionth of a degree. Another is so sensitive that it can detect heat given off by a person's body when the person is so far away that he cannot be seen with the naked eye.

SUMMARY · [E]The use of such inventions as these has made it possible for man to become more sensitive to his environment than is any

[2]*Thermocouple* (thûr'mō kŭp'l).

other living thing. Such extreme sensitivity, coupled with the extension of his muscular system through the use of machines, has given him, within the past few years, a greater variety of behaviors than could have been imagined a century ago. It seems reasonable to expect that future progress in providing wide varieties of behavior through further supplementing of the senses will be even more rapid.

Checking What You Know

BIOLOGICAL FACTS · (*Do not write in this book.*) **Pages 375–386.** **1.** Three systems involved in the control of the behavior of animals are --?--, --?--, and --?-- systems.

2. Of the three special kinds of neurons, those that cause movements are --?-- neurons; those that connect different organs are --?--; and those that make an animal aware of conditions in its habitat are --?--.

3. Of the three divisions of the central nervous system, that which causes the muscles to act properly together is the *cerebrum*; that which controls involuntary actions involved in the body processes is the *cerebrum also*; and that which controls learning, planning, and remembering is the *medulla oblongata*.

4. The autonomic nervous system functions in close association with the *cerebrum* in the control of *voluntary* actions.

5. Many reflex acts are controlled by the *backbone*.

6. When you throw a ball, you are using *voluntary* muscles, or *smooth* muscles, in your arm. The muscles in your artery walls are *also voluntary*, or *striped*, muscles.

7. Of the various kinds of joints, those that permit the greatest freedom and variety of movement are *hinge* joints.

8. Bones are held together at the joints by means of (1) tendons; (2) ligaments; (3) muscles; (4) nerves; (5) hinges.

9. State three functions of an animal's skeleton.

10. Plants have *few* muscles, and hence their actions are relatively *slow*.

Pages 386–402. **11.** *All* human senses are keener than the corresponding senses of all other animals.

12. Most animals and at least some plants feel vibrations, but probably only the higher *invertebrates* hear sounds.

13. Name the senses that help us to keep right side up. The most important of these is located in the *muscles*.

14. *All* animals are sensitive to light, but not many simple animals have *lens* eyes.

15. Name four senses of "touch."

16. *Smell* is a chemical sense.

17. The flavor of most foods is a blend of their --?-- and --?--.

18. Name at least five habit-forming drugs.

Pages 402–405. **19.** Man's superiority to all other living things is believed to be due largely to his superior brain and his superior --?--

BIOLOGICAL PRINCIPLES · **1.** Complex behavior involves action by the nervous system, the endocrine system, and the muscular system.

2. All the bodily functions of the higher animals are controlled by the nervous system.

3. The higher an animal is in the scale of life, the more complex are its nervous system and its behavior. This principle is often stated thus: Increasing complexity of structure goes hand in hand with division of labor.

4. All but the simpler forms of animal life have sense organs, but these vary in number, nature, and keenness.

5. To carry on the functions of higher organisms, cells are organized into tissues, tissues into organs, and organs into organ-systems.

6. Division of labor in the nervous system is accomplished by special organs that are sensitive to stimuli, such as light, heat, contact, and sound.

7. Sense organs are important factors in survival.

BIOLOGICAL TERMS

**cerebellum **medulla oblongata
**cerebrum **nerve
**spinal cord

Applying and Extending What You Know

AS SCIENTISTS WORK AND THINK · 1. Jim was having an argument with his sister, Alice. Jim insisted that boys were smarter than girls. He said that men in general had larger brains than women, and hence must be smarter.

"That isn't so," said his sister. "Girls are smarter than boys. Just look at the list of honor students in the last school paper. There are forty-eight girls on the list and only thirty-two boys. So there you are!"

"That doesn't prove anything," Jim replied, "except that there are more bookworms among the girls than among the boys in our school. Just look at all the great persons in history. How many of them have been women?"

What scientific attitudes relate to this conversation?

2. During the Second World War sound-detectors were used on war-ships to detect submarines and other enemy vessels. Soon after they were put into use, however, a difficulty arose. The men who operated the sound-detectors found that they could detect sounds, but could not determine what caused them. It was suggested that these sounds might be made by fish and other sea animals. Plan an experiment by which you think it would be possible to determine whether the detected sounds were caused by fish or by ship propellers. Indicate the elements of scientific method which would be used in your plan.

3. An ant was put from its own nest into another. It was promptly attacked and killed. The experiment was repeated with another ant, but this one was carefully washed in alcohol to remove its characteristic odor. When it was transferred, it was not harmed. What inferences[1] can be drawn from this experiment?

CONSUMER BIOLOGY · 1. Some people who need glasses select them by merely trying on different pairs from a tray displayed in a store. What dangers are there in such a practice?

2. Examine the labels on containers of cosmetics. Note which, if any, give warning of possible dangers from their use. Find out from your druggist what kinds of face powders are specially prepared for people who are allergic to orris-root.

3. Find out from your druggist what drugs cannot be sold directly or used in medicines except when prescribed by a physician. Find out which of these are included among habit-forming drugs.

APPLYING YOUR KNOWLEDGE OF BIOLOGY · 1. If you were blindfolded and your finger were pressed against either a hot object or an extremely cold object, such as a cake of Dry Ice, you would not be able to tell which you had touched. Why not?

2. Explain why neither babies nor old people have senses as keen as those of other people.

3. In testing the temperature of a baby's bath water, the mother often puts her elbow into the water instead of her hand. Why?

4. Some persons can feel the vibrations of the lowest notes of an organ, but cannot hear them. Explain.

5. Ants follow their burrows by feeling the

[1] Page 570, No. 10.

As has been stated, man's brain is superior to the corresponding organ of every other living thing. Moreover, man's hand is adapted to finer adjustments than are the grasping organs of any other animals except, perhaps, certain great apes. How do these facts apply to the statement "Man's brain and hand together have made possible all inventions and all progress"?

walls with their antennae. A cockroach follows a wall by feeling it with its antennae until it locates a crevice, into which it darts. A beetle will crawl along a stick until it comes to the end, then feel all around with its front legs for something to support it. If it finds nothing, it will usually go back down the stick. Which of the specialized nerves of touch do you think are used by these animals in these behaviors?

6. The Protozoa have no nerve structures. How do you account, therefore, for their quick reactions to stimuli?

TOPICS FOR INDIVIDUAL STUDY · 1. Some of the small crustaceans seem to have only one eye. Consult an advanced textbook of zoology or an encyclopedia to find out whether this eye is really a single, simple eye.

2. The nautilus has a "pit eye," which is more like the camera eye than like any other. Consult an advanced textbook of zoology to find out what the structure of the pit eye is and how it functions.

3. Consult a textbook of high-school physics for additional information on sound. Try to find out why sounds differ in loudness and in pitch, how rapidly sound travels, how the temperature of the air affects the speed of sound, what kinds of sounds cannot be heard by the human ear, etc.

4. Consult a textbook of high-school physics to learn more about light. Find out what light is, how fast it travels, how it is used in optical instruments, etc.

5. From textbooks of physiology or of high-school physics find out how eye-glasses correct defective vision.

6. Consult an advanced textbook of physiology to find out on what parts of the tongue, mouth, and throat the various kinds of taste buds are located.

7. From your local board of health or your state or provincial department of health find out what agencies are responsible for enforcing the laws governing habit-forming drugs.

EXPERIMENT · What is the average reaction time of the members of your class? The reaction time of a person is the time from the instant when a stimulus is received until his muscles react to the stimulus. For example, about $\frac{4}{5}$ of a second passes from the instant that the average driver sees a red traffic light until he applies his foot to the brake pedal of his automobile. That is his reaction time.

To find out the average reaction time of the members of your class, proceed as follows: The students and the teacher form a circle by holding hands. One member of the class acts as the timer, using a stop watch, which may usually be borrowed from the athletic coach or the physics department. All the persons in the circle close their eyes. The timer waits until the second hand is exactly on a convenient division on the watch dial. At that instant he touches the teacher's arm. The teacher squeezes the hand of the student on his right. As soon as the student feels this squeeze, he squeezes the hand of the student on his right, and so on around the circle. At the exact moment when the teacher's left hand is squeezed, he calls out, "Time!" The timer stops the stop watch, and the time that has passed since he started the reactions around the circle is written down. The average time of reaction is obtained by dividing this time by the number of persons in the circle, plus the timer, who must be counted twice. Why?

What is the average reaction time of the members of your class?

COMMUNITY APPLICATION OF BIOLOGY · **Investigating provisions for conserving vision and hearing.** In many schools the vision and the hearing of the students are tested regularly. Find out from the school physician or the school nurse how these tests are conducted; what kinds of instruments are used in making the tests; how frequently the tests are made; and what percentage of boys and girls have defective vision or hearing. Find out whether your community does anything to help to correct these defects.

15

CHANGING AND CONTROLLING BEHAVIORS FOR SUCCESSFUL LIVING

How Is Learning Effected?

Boots, an "educated" dog that has appeared in the motion pictures, has learned to do an amazing number of "tricks." It is said that she will respond correctly to eighteen hundred different words, recognize all the letters of the alphabet when they are written, and obey orders even when they are written on a black-board instead of being spoken to her. She is said not only to have learned to untie certain simple kinds of knots in a rope, but also to have succeeded sometimes in untying more complex knots of a type that she had never seen before.

There is no doubt that Boots is an extraordinarily intelligent dog. Probably not one dog in a million would be capable of learning as many tricks as she has learned. But anybody who is familiar with dogs knows that almost any dog can be taught to change some of its normal behaviors.

If the same "little dogie" were lassoed frequently, it probably would learn to stop as soon as it felt the rope around its leg. Can you explain why before reading farther?

Swift and Company

CONDITIONED REACTIONS · Pavlov[1] was a pioneer investigator of ways in which the normal reactions of animals can be changed through training. In one of his early experiments he showed a hungry dog some meat as a stimulus. He observed that saliva immediately began to collect in the dog's mouth. This response was a natural reflex.

Pavlov next tried the effect of presenting another stimulus along with the first one. He rang a bell at the same time that he showed meat to the dog. Each time that he did so, saliva collected in the dog's mouth, just as it had done when only the meat was shown.

After presenting both stimuli together for a number of times, Pavlov rang the bell without showing the meat. Saliva collected in the dog's mouth, just as before. Thus Pavlov had succeeded in substituting a new stimulus for the normal one and still getting the same reflex action.

[1]Page 357.

The "movie star" Lassie, feeding a lamb · Would you infer that Lassie is above or below average intelligence for a dog? Explain

Metro-Goldwyn-Mayer

Pavlov made similar experiments with other dogs, using different stimuli along with the meat. In many cases he had results like those first secured. He called this process of substituting one stimulus for another to secure a certain response "conditioning." He called a reflex caused by a stimulus different from the one that normally produces it a "conditioned reflex."

Pavlov's method of conditioning has been tried by numerous investigators with many kinds of vertebrates and even some invertebrates. One investigator succeeded in producing the chewing response in a snail by touching its foot. Normally, this response results only when a snail's mouth is touched with suitable food. For two hundred and fifty times the snail's foot was touched at the same time that its mouth was touched with lettuce. The chewing reflex resulted each time. Then only its foot was touched, and no lettuce was brought near it. The chewing response followed, as before. After twelve more trials, however, the snail did not respond by chewing when only its foot was touched. Another investigator conditioned, or trained, fish to swim rapidly at the sight of a flashing light.

SUMMARY OF CONDITIONING · [E]From the results of all such experiments scientists have concluded that (1) all learning is conditioning; (2) almost any animal can be conditioned, that is, almost any animal can learn new behaviors; (3) [P]in general, the more complex and highly developed an animal is, the more easily it can be conditioned, or, in other words, the more easily it will learn (illustration on this page); (4) [P]conditioned responses are not permanent, that is, animals readily "forget" abnormal behaviors that they have learned; and (5) among animals of the same kind, some learn more easily and forget more easily than others.

NATURAL AND ARTIFICIAL CONDITIONING · All the higher animals, and, to a limited extent, the simpler animals also, modify their behaviors through the processes of conditioning as they grow to maturity. Such learning is natural conditioning. Man, however, brings about artificial conditioning (illustration, p. 409).

From the time, ages ago, when some person tamed the first animal that was ever tamed, to the present, man has been conditioning animals for his advantage. Of far more importance than this, however, is the conditioning that people have been giving, and to an increasing extent are giving, one another and themselves. We are taught how to play games, how to make a living, and how to do all the things necessary to enable us to live effectively in a civilized nation and world (illustration, p. 412).

Teaching

CONDITIONING OF HUMAN BEINGS · All but the simplest unlearned behaviors of human beings are conditioned responses. Even a young baby soon becomes conditioned. It learns early, for example, to respond to its mother's voice. Its reflexes and instincts become modified so that a new stimulus, such as the sight of the nursing bottle, causes an old response—in this case, the sucking reflex. It is difficult to recognize instincts in adults because of the conditioning that they have had. For this reason most of the study of human instincts is carried on with babies.

Many people, especially children, have fears and prejudices that are not reasonable and that cause them and others much unhappiness. For example, many children are afraid of the dark. Others are afraid of all snakes. Still others dislike cats, though they may not fear them. You can doubtless think of many other examples of this sort.

It is said that man has only two instinctive fears, namely, the fear of falling and the fear of loud noises. All other fears and all prejudices are believed to be acquired through conditioning. For example, at some time in a child's early life, he learned to fear the dark, perhaps because some older children frightened him when he was in the dark. He probably became afraid of snakes by observing that some older person feared them. He may have become prejudiced against cats by observing somebody else's dislike of them. The stimulus furnished by the dark, a snake, or a cat became associated with an unpleasant response.

Fears and prejudices of this sort can often be removed by further conditioning. This is done by substituting, in connection with the thing feared or disliked, a pleasant association for an unpleasant one. For example, a child who fears the dark may gradually lose this fear if he is allowed often to hear music while in the dark. He may be able in time to substitute curiosity about snakes for his fear of them, if he is encouraged to study their life habits. He may get rid of his prejudice against cats by watching a kitten at play. A little boy helped to condition his younger sister so that she lost her fear of nightmares, by telling her that whenever he was waked by a bad dream, he immediately thought of a cooky and at once forgot about the dream.

Our knowledge of how conditioning is accomplished can be put to many practical and social uses. Dentists suggest that young children be brought regularly to their offices and seated in a dental chair even when their teeth do not need attention, in order that they may become familiar with such surroundings. One dentist gives an ice-cream cone to every child who makes such a visit. This treatment is planned to prevent the child from developing a fear of dentists.

A child's attitude toward a policeman can

a habit a learned involuntary behaviour

Here are four types of planned learning experiences. Can you name others? How is artificial conditioning taking place in each of these scenes?

be made one of fear or one of trust, by the way in which the conditioning is done. Many other examples could be given to show that the conditioning which young children receive can prove a strong help or a serious handicap to them in later years (illustration, p. 414).

HABITS · Habit-forming is conditioning that is brought about in our thinking processes, our emotions, our physical reactions—in fact, in all aspects of our behavior. The first dog mentioned in the account of Pavlov's experiments formed the habit of secreting saliva when he heard the bell. The snail[1] formed the habit of chewing when its foot was touched.

A habit is like a reflex and an instinct in being an involuntary behavior. Also, complex habits are like instincts in consisting of chains, or series, of responses,[2] in which each response in its turn serves as the stimulus for the next response in the chain. A habit is unlike a reflex and an instinct in being a learned reaction.

No habit formed by any animal, except man, is believed to be purposely, or intentionally, formed. A hen forms the habit of going to the same nest to lay her eggs. Cows form the habit of going to the barn at milking time. The hen and the cows, however, do not learn these behaviors intentionally.

Even people do not intentionally form all

[1]Page 410.

[2]Page 361.

the habits that they have. You may use a certain expression much too often in your conversation, or you may "play with your hair" while studying. If so, you probably formed the habit through chance repetitions of the act. You may not even be conscious that you have this habit. You do not form such a habit purposely, but unlike the hen, the cows, and all other animals, you *can* form habits purposely, and break them purposely.

FORMING AND BREAKING HABITS · Do you remember how you learned to "do" your hair, to tie your tie, to write on a typewriter, to ride a bicycle, to play a game of tennis, or to swim? At first, you had to think of every motion as you made it. You made many motions which did not give the desired results. You had to practice repeatedly, giving your attention to developing the correct motions and avoiding the incorrect ones. Finally you reached a point where you could perform the act expertly without having to think about it. Thus you had intentionally developed a habit.

[E]Anybody can form a habit that he wants to form. Also, he can substitute a new habit for an undesired one or break an undesirable one.

[E]In acquiring a habit or in changing one a person follows these steps: (1) He must decide exactly what the habit is that he wants to establish, and he must make certain also that he really wants to form it. It is useless for him to try to form a habit that he would rather not form. (2) He must then practice the act with careful attention to ensure that he always performs it correctly. Remember that it is not mere practice that makes perfect, but only *correct* practice that makes perfect. (3) He must perform the act at every opportunity, and always correctly. Thus he "fixes" the habit.

Here is an example to show how these rules are applied: Suppose that you have become aware that your speaking voice is less pleasing than you would like it to be. Suppose that you decide to improve it. Perhaps you know that you speak too loudly, not distinctly, or with a whine or an ill-natured tone. First, you decide what change you want to bring about. You listen carefully to the speech of somebody who speaks in the way in which you would like to speak. You try to imitate his way of speaking. You keep trying until you happen to get what seems to you to be the desired effect. Perhaps then you try this new way of speaking before a friend, in order that he may give you suggestions and criticisms.

When you are sure that you have discovered how to speak in the way that you desire, or as nearly in that way as possible, you note carefully how your lips and tongue are placed and how they feel, and how your throat feels, when you are speaking in this way. Thus you determine the new nerve pattern to be established. Then you begin to put the new behavior into practice. Whenever you speak, you think first about how you are going to do it. You are careful always to speak only in the way that you have decided upon. You guard against going back to your former way of speaking.

At first, it is difficult to make such a change. It is never easy to substitute a new nerve pattern for an old, well-formed one. You need to keep your attention fixed upon speaking in the new way. Your actions are therefore voluntary and conscious ones. They are controlled by the cortex of your cerebrum. During the process of forming the habit, however, the control of the reaction passes from the higher to the lower brain centers.

Finally you reach the stage in which you use the new way of speaking without having

to think about it at all. You have then succeeded in establishing the new nerve pattern. The new way of speaking has become a habit. In other words, the new behavior has become involuntary and is entirely controlled by the lower brain centers.

By following the same rules, one can form or change emotional habits, such as controlling one's temper, overcoming a tendency to be jealous, modifying intense dislikes, and acquiring a feeling of patriotism.

[E]The steps followed in breaking a habit are essentially the same as those followed in forming one. After a person has "made up his mind" to break a habit, such as biting his finger-nails or humming, he must practice not doing it. In other words, he must do his best never to perform the act again. If he tries to "taper off," he is not likely to succeed in breaking the habit at all, because each time he repeats the act, he strengthens the nerve paths that he wants to weaken or if possible destroy.

It is evident that this man has no fear of this young octopus. Can you suggest how such conditioning as this picture indicates might have been brought about?

Lewis Wayne Walker

FACTORS AFFECTING LEARNING · Most of the experimenting to find out how learning takes place has been done with the higher vertebrates. Such animals are used because with them all parts of the experiment can be so carefully controlled that the results are likely to be accurate. Experiments of this kind are of great value because much that is discovered about how animals learn can be used in helping people to learn. Some of the important factors, or conditions, that have been found to affect learning include experience, pleasure or annoyance (displeasure), and attention.

Experience. Let us suppose that a puppy meets a cat for the first time. If the puppy happens to bark and the cat runs away, the puppy will be likely to bark the next time that it encounters a cat. But if, instead of barking, the puppy happens to run up to the cat and get scratched, it will probably run away from the next cat that it meets. Thus through experience the puppy learns what is, for it, an important lesson, and what it learns will affect its future behavior in situations involving cats.

In the example just given, the puppy employs trial and error in solving its problem of what to do about the cat. It is important to note that trial and error plays an important part in all learning by experience. When-

ever an animal meets a new situation that requires a response on its part, it employs trial and error. It responds in one of the ways that its structures make possible. If the response is successful, the animal is likely to respond in the same way when it again meets the same situation. If its response is not successful, it will probably try some other response the next time. It will continue to try, one after another, all the different responses that it can make, until either by chance it hits upon a successful response or it suffers the consequences of being unable to make a successful one.

No doubt you have often "worked" a metal puzzle of the kind made of heavy twisted wire which you were supposed to solve by removing or shifting a part. You turned and twisted the parts this way and that until, largely by chance, through trial and error, you finally hit upon the correct way. A number of examples of learning by experience gained through trial and error are indicated in the paragraphs that discuss making and breaking habits. Many more are suggested in the following pages.

Experiments with many kinds of animals have resulted in the animals' learning new responses through their experiences. To illustrate: Although a cockroach normally seeks to avoid light, a group of cockroaches soon learned to stay in the light as a result of experiencing an electric shock whenever they went into the darkened area of their cage. A green tree frog hopped twenty-five times before reaching a tank of water placed in its cage and purposely hidden from its view by some objects. After one hundred trips, however, it had learned to reach the tank by a route which required only eight hops. It continued to go to the tank by the short route during each of ten more trips.

A turtle, when first placed in a box in which its nest was hidden by a number of obstacles, took one hour and thirty-five minutes to find its way to its nest. After forty-nine trials, however, it had learned to follow the shortest route to its nest and to reach it in a little more than four minutes.

In all these cases the animals obviously changed their behaviors through experience. New nerve paths became involved in the behavior in place of the original ones. In repeating the actions the animals learned to eliminate errors and false motions. By so doing they made definite the nerve patterns involved in the correct responses and thus established habits. By repeating the correct responses after learning them, they strengthened the newly formed nerve patterns and therefore strengthened the habits.

Pleasure or annoyance. Whether experiences are pleasant or unpleasant has a strong effect upon learning. What happens to an animal as a result of what it does tends to make it repeat or not to repeat the behavior. Principles which investigators have discovered relative to pleasure, or satisfaction, and annoyance, or pain, in learning include the following:

1. [P]Animals tend not to repeat responses that have given them pain or discomfort. Groups of hogs can be kept apart by an "electric fence" consisting of a single wire through which current is flowing. After they have touched the wire and received an electric shock once, they make no further attempts to cross over it (illustration, p. 409)

Investigators have learned that, in experiments such as these, if a punishment is given for the wrong response, it must not be too severe. It was found, for example, that if the shock that rats received for picking out wrong cards was too strong, they did not thereafter perform at all.

2. [P]A satisfaction associated with the cor-

rect response results in more rapid learning than when a satisfaction is absent. An investigator gave food to one group of rats each time after they had found their way through a maze, and no reward to another group of rats for doing the same thing. The rats that were rewarded all learned to follow the correct route more quickly than the ones that were not.

3. A reward for a correct response is usually more effective than a punishment for a wrong one. A correct combination, however, of pleasure and annoyance associated with a response provides the best condition for rapid learning. At the Seeing Eye, an institution in which dogs are trained to guide and protect blind people, it has been found that dogs learn fastest if they are sharply corrected when they make a mistake and are then praised when they make the correct response. The combination of "satisfier" and "annoyer" brings about more rapid learning because it makes use of both the tendency to avoid an unpleasant situation and the tendency to seek a pleasant one.

4. Learning is more rapid if the reward for the correct response satisfies an immediate need of the animal. The frog previously mentioned was stimulated to find the shortest way to reach the tank because it wanted the protecting shelter afforded by the water. Thirsty rats have been found to learn faster when given water, rather than food, as a reward for making the desired responses. Likewise, hungry rats have been found to perform best for food.

Attention. In studying the learning of animals, investigators have sometimes been puzzled by getting results exactly opposite to those expected. In one experiment rats made fewer errors in getting to hidden food the first time than they did in many later trials. They had been expected, on the basis of other similar experiments, to make fewer errors after the first trial. Other animals were found to learn new behaviors more readily when transferred to a different laboratory, even when the conditions in both laboratories were believed to be similar.

In trying to account for such unexpected behaviors, the investigators concluded that they had overlooked the factor of attention. In the cases in which the animals performed best the first time, they were evidently curious about their new environment, and consequently paid closer attention to it in making their responses than they did later. But when the novelty had worn off, the animals gave more attention to noise, to someone moving in the room, or some other stimulus, and hence gave a much less perfect performance. When all such distracting stimuli were removed, the animals again performed better.

In another experiment animals were provided with a second and longer way of getting to their food after they had learned one way. In their first attempts to reach the food thereafter, they nearly always took the new way. They continued to do this until they had thoroughly explored it. Apparently the novelty of the new path drew their attention away from the old, and provided a stronger stimulus than the desire to reach the food by the well-known path. But as the animals became familiar with the new path, the strength of the stimulus which caused them to take it diminished, and they again chose the shorter path in later trials.

Thinking process

DELAYED RESPONSES · All learning is made possible by delayed responses. As has been stated earlier, an unlearned behavior, such as a reflex or an instinctive action, normally begins as soon as the stimulus is sensed. There is no delay in the response. As long as the

I. Q. is imp here also

Most people form the habit of maintaining poor posture while standing, sitting, or walking. In some cases poor posture (*A*, *A*, and *C*, *C*) leads to poor health. It robs the internal organs of the full support of the pelvis. In all cases good posture (*B*) makes people more attractive. Can you outline the steps by which one could form the habit of maintaining good posture?

response to a stimulus is immediate, an animal cannot make any new responses to the stimulus. It can only repeat the action as often as the stimulus occurs. Therefore no conditioning is brought about. No learning takes place. If, however, the animal can be caused to delay its reaction to a stimulus for even an instant, then it can learn new responses.

If the pleasure or annoyance experienced, the novelty presented, or other conditions attached to the reaction are strong enough, practically any animal, even a protozoan, can and will delay its normal response to a stimulus. Consequently it is able to make a new response. In other words, it is able to learn. Thus the cockroaches that learned to stay in the light learned, because of the unpleasant electric shock that they received, to suppress their normal response, which is to avoid light. The animals that explored a new way of reaching their food did so because the stimulus provided by the new path was strong enough to cause them to delay their accustomed response to the stimulus to follow the familiar path.

HUMAN LEARNING · [E]Human beings are like, rather than unlike, other animals in the ways in which they learn. The same factors that cause all other animals to learn are effective with us also. Every child begins to learn

Acme

Even in performing skills that have become more or less fixed habits there is usually much waste motion. The white lines show the motions that the woman made in making the bed. **Topics for Individual Study:** What is done to improve the skills of workers in industrial plants? Make a study of some skill of yours which you have developed into a fixed habit, to see whether there is waste motion. Then change your habit so as to get rid of the waste motion

from his experiences almost from birth. All through life people tend to repeat behaviors that are associated with pleasant consequences and to avoid repeating those that give pain or other annoyance.

[E]As has been repeatedly indicated, animals learn by chance experiences, and human beings do also. Thus a child may learn by chance that rose thorns scratch painfully. But, unlike all other animals, human beings carefully plan and provide most of the learning experiences for others and for themselves (illustration, p. 419). The differences between man and all other animals, which are now so great, will become greater as we learn more and more effective ways of providing desirable learning experiences.

UNCONSCIOUS MEMORIES · Often people have experiences which they later forget; yet the experiences remain stored as unconscious memories in the brain. Later these memories cause the people to behave in ways that can be explained only in terms of the

memories. To illustrate: Nearly a hundred years ago, in England, the newspapers were filled with accounts of a strange mystery. An ignorant old woman, while "out of her head" (delirious) during illness, had frightened the simple folk who were taking care of her by speaking in strange tongues. Later, scientists had been called to her bedside. They had recognized the languages as Latin and Greek. The old woman had quoted long passages of Latin and Greek poetry correctly, and with an almost perfect accent.

The woman had been a house servant all her life. She was ignorant, having had scarcely any schooling and being hardly able to read the simplest English. People generally believed, therefore, that her sudden ability to quote the Greek and Latin poets was some sort of miracle, a "gift of tongues." Scientists, however, looked for a natural explanation.

They carefully traced her life history. They found that early in her life she had served as housemaid in the home of a noted Latin-and-Greek scholar. As she had gone about her sweeping and dusting, she had heard this man reciting Greek and Latin poetry. She had understood none of it. She had not even paid any attention to it. Yet the experience had been recorded in her brain. She had never afterward spoken any Latin or Greek words when conscious, and probably could not have spoken them even if she had so wished. But, when unconscious, she recalled passages which she had heard recited so many years before.

Are these planned learning experiences? Explain. Which of these learning experiences are intended to result in habit formation?

Press Association

Do you think that these paratroopers learned by trial and error how to leap from a plane and land safely? Explain

Checking What You Know

BIOLOGICAL FACTS · (*Do not write in this book.*) **Pages 409–419.** **1.** State the five facts which summarize what scientists have learned from experiments on the conditioning of animals.

2. A child's learning not to put his finger in a flame is an example of __?__ conditioning; his learning how to comb his hair is an example of __?__ conditioning.

3. *All* fears and prejudices are the results of conditioning, and *all* fears and prejudices can be removed by further conditioning.

4. Human instincts are easier to study in *adults* than in *infants.*

5. *Like* reflexes and instincts, habits are *learned* reactions.

6. State three steps needed in establishing a habit.

7. In breaking a habit one should stop the undesired act *gradually.*

8. State the four principles that apply to the use of satisfaction and annoyance in causing animals to learn.

9. Learning is more rapidly brought about by (1) natural experience; (2) punishment; (3) reward; (4) neither punishment nor reward; (5) a combination of punishment and reward.

10. Animals making immediate responses to a stimulus are *most easily* conditioned.

11. Human learning is more *like* than *unlike* animal learning.

12. Education is a process of learning through *chance* experiences.

13. Many forgotten human experiences remain as *unconscious* memories.

BIOLOGICAL PRINCIPLES · 1. The natural behavior of animals can be changed, or conditioned.

2. Animals with complex nervous systems may be conditioned more readily than those with simpler nervous systems.

3. The survival of an organism depends largely on how it reacts to stimuli.

Applying and Extending What You Know

AS SCIENTISTS WORK AND THINK · 1. The advertisers of many products try to condition your behavior and change some of your habits. Newspaper, magazine, billboard, and radio advertising is intended to persuade you to try new products in place of those that you are now using, or to buy things that you have not been buying. Study the advertisements of some well-known products to determine what kinds of appeals they make to you. Which of the scientific attitudes should the person who reads or hears these advertisements possess? Which of the scientific attitudes is most closely related to the term *sales resistance*?

2. What elements of scientific method did Pavlov use in his experiments on the conditioning of reflexes in dogs?

3. What scientific attitudes are indicated in the incident of the woman who recited Latin and Greek poetry that she had never studied?

CONSUMER BIOLOGY · 1. What kinds of conditioned behaviors are important to consider in buying a riding horse, or in buying a canary, a parrot, or other pet?

2. Before you decide to attend a certain school or to study with a certain music teacher, what do you try to find out about the kinds of conditioning that you may expect to receive?

3. What are some habits that you should establish so that they will function when you are buying foods?

How would you explain the monkey's behavior here?

Signal Corps, from Science Service

APPLYING YOUR KNOWLEDGE OF BIOLOGY · 1. How would you train a young dog so that it would not eat food that it might happen to find, or allow itself to be fed by anyone but you?

2. A hawk was observed to seize a young jack rabbit in its talons and try to fly off with it. The rabbit struggled so violently that the hawk's flight was difficult. The hawk managed to carry the rabbit about fifty feet into the air, and then dropped it. The bird repeated this action four or five times. It then carried the dead animal away. How would you explain the hawk's behavior?

3. There is a common saying that "experience is the best teacher." In speaking of animal learning, and of much human learning, probably most biologists would say that "experience is the *only* teacher." Explain this statement.

4. If you happen to be "hot-tempered," you may have been advised to count to ten before doing anything when your temper was stirred. In view of what you have learned from the preceding pages, is this good advice? Why?

5. Are you satisfied with the results of your school-work? How can you improve it? How can you improve your study habits? Make a list of suggestions for improving your study habits. Put these suggestions to the test to see whether your school-work improves.

6. How do people develop undesirable habits? Make a list of several such habits and state the steps that should be taken to break them. If you have any such habits, try your suggestions on yourself.

7. How have you been conditioned by your schooling? How might you be different had you never attended school? What are some specific ways in which your education has affected your behavior? How have such influences as the church that you attend; the books, magazines, and newspapers that you read; or the motion pictures that you see affected your behavior?

8. Give several examples from this chapter or from your own experience which show how man has used conditioning in controlling living things for his advantage.

9. You can close your eyes and feel a baseball and a basketball and easily tell which is which. You can do the same with a head of lettuce and a cabbage. Neither a child nor an adult Eskimo, however, could do this. Explain.

10. Young chicks peck at anything that attracts their attention. They soon modify this reflex so that they pick up chiefly food. Can you explain how such conditioning might be brought about?

A Seeing Eye dog at work · How is this illustration related to that on page 2?

The Seeing Eye

TOPIC FOR INDIVIDUAL STUDY · In a book like Arnold Gesell and Frances L. Ilg's *Infant*

and Child in the Culture of Today (Harper & Brothers), read about the progressive development of a child from its birth until it is five years old. Take notes on how the child learns to use its arms and legs, how it responds to its meals and its bath, how its sleeping habits change, and other similar information. Prepare an oral report to be given in class, in your home room, or in the science club.

EXPERIMENT · Can the behavior of a fish be changed? Obtain three or four goldfish, which can be kept in an aquarium in the biology class-room. See how the fish react when you tap with the point of a pencil against the side of the aquarium. Do this a number of times during several days in succession. Why? Then for a week or two tap the side of the aquarium at the instant when you drop food into the water. During this time be sure that the aquarium is never tapped or jarred except when food is being dropped into it. Do the fish show any evidence of conditioning?

Later tap the aquarium without dropping in any food. How do the fish respond? Each day from then on, do not tap or jar the aquarium when you give the fish food, but tap it at other times. How long do the fish continue to look for food when the tapping is done? What have you learned about the ability of a fish to remember a response which it has learned?

GROUP INVESTIGATION · *To study student behaviors.* The rules under which your school operates were written with the intention of changing the behaviors of those boys and girls whose behaviors must be changed in order that the school may be conducted efficiently. Study the rules and regulations. Then make observations in and about the school to see how successfully the behaviors of the students have been conditioned in the desired ways. Determine whether the students observe hall regulations, and how they behave in the school cafeteria, at athletic contests, during assemblies, etc. Organize a panel discussion[1] of your observations and your suggestions for improvement.

PANEL DISCUSSION · Topic: Unlearned behaviors are of more importance to survival than learned behaviors.

BIOLOGY IN THE NEWS · 1. Watch for articles in newspapers and magazines concerning habit-forming drugs. Look for articles dealing with the ill effects of these drugs on human beings. Note also any mention of helpful uses of such drugs, as their use in medicine.

2. Look for articles in newspapers and magazines on the causes of automobile accidents. Note particularly articles telling of accidents caused by intoxicated drivers. Try to determine whether there is any truth in the saying that "alcohol and gasoline do not mix."

BOOKS FOR REFERENCE

Dorsey, G. E. *Why We Behave like Human Beings.* Harper & Brothers.

Emerson, Haven, and others. *Alcohol and Man.* D. Appleton-Century Company, Inc.

Gesell, Arnold, and Ilg, Frances L. *Infant and Child in the Culture of Today.* Harper & Brothers.

Kahn, Fritz. *Man in Structure and Function*, Vol. II. Alfred A. Knopf.

BOOKS FOR LEISURE READING

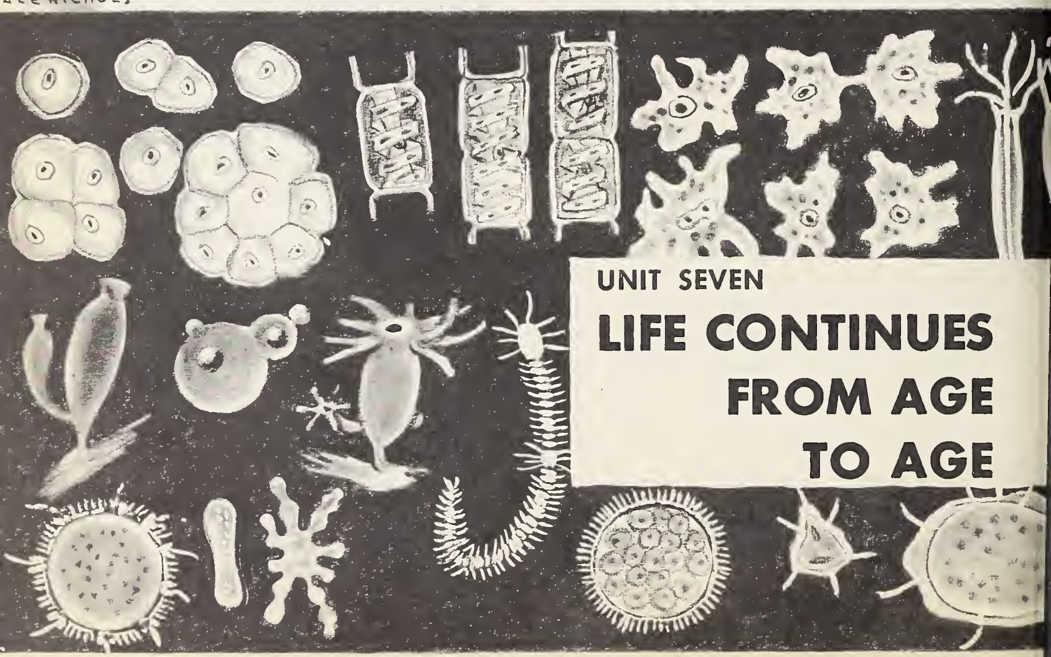
Allee, W. C. *Social Life of Animals.* W. W. Norton & Company, Inc.

Dinesen, Isak. *Out of Africa.* Random House, Inc.

Pitt, Frances. *The Animal Mind.* G. Allen and Unwin, London.

Wheeler, W. M. *Social Life among the Insects.* Harcourt, Brace and Company.

[1]Page 116.



UNIT SEVEN

LIFE CONTINUES FROM AGE TO AGE

What are the various ways in which plants and animals, from the lowest to the highest forms, reproduce their kinds?

How does the earth's population change from age to age?

How can man apply his knowledge of reproduction and inheritance in improving living things?

Knell from U.S.D.A.

Why do you think this illustration was placed here?

YOU HAVE PROBABLY HEARD the old saying "Truth is stranger than fiction." This saying might easily have had its beginning in the study of biology. Surely nobody could "make up" anything so fantastic as the facts about the ways of life of many plants and animals. The life history of the horse-hair snake is only one of many complex life histories that biologists have pieced together, bit by bit, through many years of patient investigating.

The adult worm lives in water. There, in the fall or spring, it lays its eggs. Soon after the larvae, or young horse-hair snakes, hatch from these eggs, each enters the body of almost any kind of aquatic insect that may be in the habitat, such as the larva of a May fly. There it encysts[1] itself; that is, it forms around itself

[1]*Encyst* (ĕn sĭst′)

a tough protective wall, and thus becomes a cyst. By the time its insect host is ready to leave the water as an adult, the young horse-hair snake inside it has completed a certain part of its life history.

Soon after leaving the water the host dies, either because it naturally does not live long or because it has been badly injured by the parasite inside it. But the encysted worm remains alive for a long time in its dead host's body.

Another insect, usually a grasshopper or a cricket, finds the dead insect host and eats both it and the cyst. The worm, protected by its surrounding wall, is not harmed. The wall dissolves in the digestive fluids of the insect, and thus the worm is released. The horse-hair snake then continues its life as a parasite in the body cavity of this second host.

In the fall, while flying or hopping about, the host may land in water. If it does, the worm leaves its body at once and from then on lives in the water. There it mates and lays its eggs. In the fall or the next spring the eggs hatch and the life cycle begins again.

The absurd idea that the worms develop from horse-hairs is an instance of a belief that was fairly common, even among scientists, until about a century ago. According to this belief (called the theory of spontaneous generation[1]), animals of various sorts, under exactly the right conditions, suddenly are formed and come to life out of rags, mud, decaying organic matter, and other materials that are not alive.

Which items under "As Scientists Think" are related to the theory of spontaneous generation?

Science-Club Project: Write a play based on some incident in the history of the theory of spontaneous generation, to be presented in your science club or in your school assembly. Consult an encyclopedia.

[1]*Spontaneous generation* (spŏn tā′nē ŭs jĕn ẽr ā′shŭn).

16

TYPES OF REPRODUCTION

1. What Are the Methods of Reproduction by a Single Parent?

Did you ever hear of a horse-hair snake? There are several animals commonly called by that name. None of them, however, is a snake. All are closely related kinds of roundworms.[1] They look like living, black or brown horse-hairs.

Many people who have seen horse-hair snakes in the drinking places of horses hold the superstitious belief that horse-hair snakes develop from horse-hairs. In other words, these people believe that horse-hair snakes have no parents at all.

Such an idea is, of course, absurd. [P]All living things are the offspring of other living things like themselves. The number of parents, however, may be either one or two. Some of the simplest kinds of plants are believed always to have only one parent. Between the lowest and the highest organisms are many kinds that under some circumstances have one parent, and under others two. Vertebrates always have two. So also have many invertebrates, including the horse-hair snake, whose life history is told on pages 426–427.

The production of a young plant or animal by a single parent is known as asexual*[2] reproduction. The production of an organism by two parents is known as sexual*[3] reproduction. The methods of asexual reproduction are described in the paragraphs that follow.

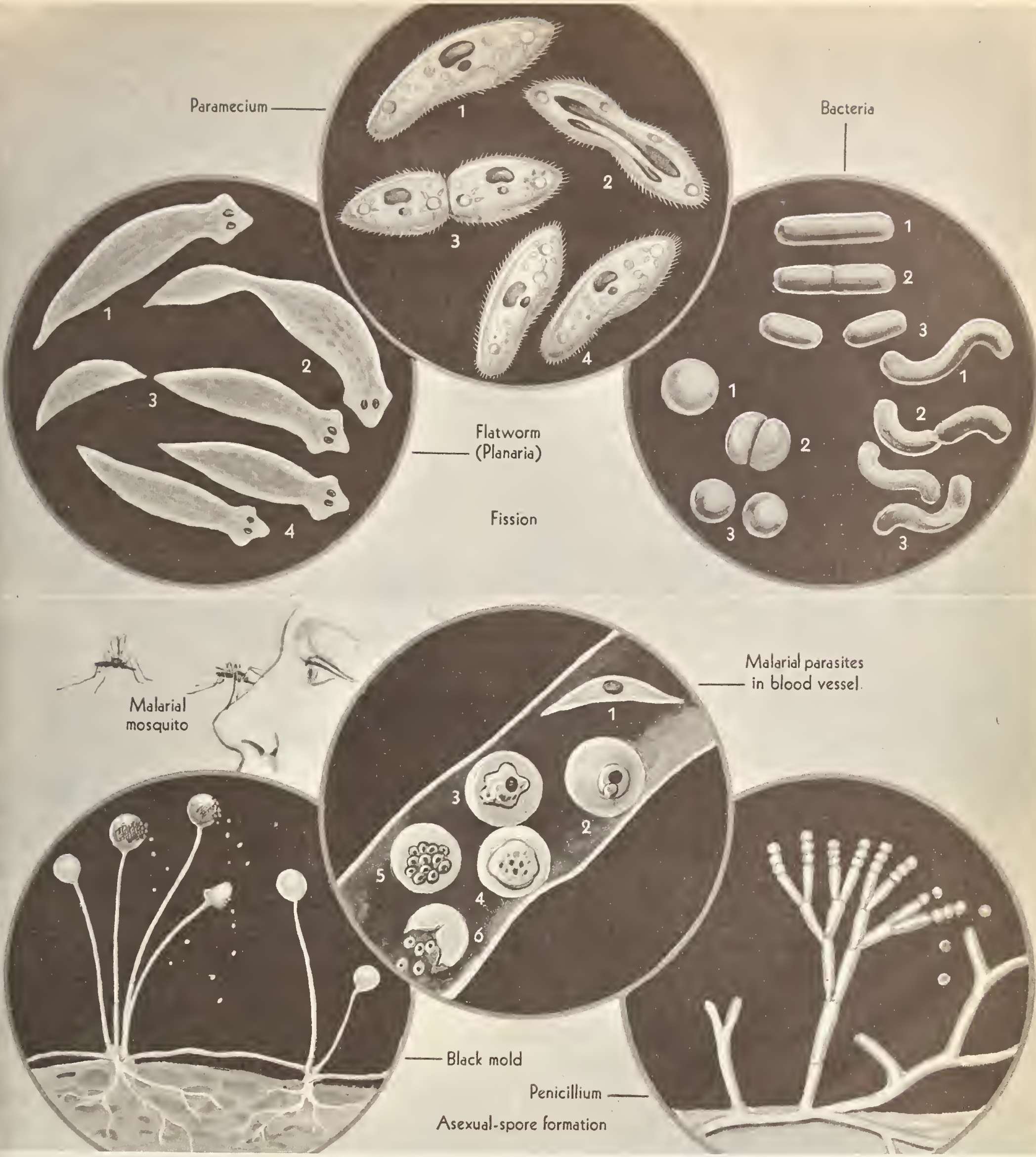
[1]Page 522.
[2]*Asexual* (ā sĕk'shŏŏ ăl).
[3]*Sexual* (sĕk'shŏŏ ăl).

ASEXUAL REPRODUCTION · **1. By division of cells.** *a. Fission.**[4] If you were to examine with a microscope the living things in a drop of the culture obtained by soaking dry grass and leaves in water for a week,[5] you might observe two paramecia attached to each other, end to end. If so, you would be observing a stage in the reproduction of *Paramecium* by fission.

Fission is the simplest method of reproduction. It is common to all one-celled plants and animals and to a few of the Metazoa. By this method, after the organism has grown to full size, it goes through certain changes and then divides in two (illustration, p. 429) to form two "daughter cells." Each daughter cell grows and becomes an individual like its parent "mother cell." As soon as it becomes mature, it too can reproduce by fission and form two new cells each time it divides.

b. Asexual-spore formation. By asexual-spore formation not two, but many new individuals are produced from a single cell by cell division. This method is fairly common with both simple plants and simple animals. For example, after several generations of an ameba or other protozoan have been repro-

[4]*Fission* (fĭsh'ŭn). [5]Pages 39–41.



Asexual reproduction by fission and asexual spore formation · After fission and asexual spore formation, the parent organism no longer exists. Its protoplasm is distributed among the new cells that are formed. Are all the new organisms thus formed of the same size? Why is it that an organism that reproduces by fission may be killed by enemies or may die if the conditions in its habitat are unfavorable, but it rarely, if ever, dies of old age?

duced by fission, usually some of the resulting animals become inactive. A thick wall forms about each of these. The nucleus then divides again and again, until there may be from eight to several hundred parts, or daughter cells, depending on the kind of protozoan involved. Each of these minute daughter cells becomes surrounded by a wall of its own, inside the parent cell wall. It is then an asexual spore. Finally the old wall breaks, and the spores are released. Under favorable conditions each spore grows into a complete individual (illustration, p. 429).

A mold plant is a common many-celled plant that produces asexual spores. As the plant develops, it sends up stalks, at the ends of which are spore-bearing structures (illustration, p. 429). Inside or upon these structures many tough-walled spores are formed. When they are sufficiently mature, they are released. They float about in the air, and whenever one settles upon a favorable spot, it develops into another mold plant.

Many algae produce asexual spores that have flagella. With these flagella the spores swim about, sometimes for several days, before they finally settle to the bottom of the body of water. There, under favorable conditions, they grow into new plants. The biologists who first observed these swimming spores (zoospores[1]) thought that they were small animals because they could swim.

2. **By vegetative reproduction, or vegetative propagation.** *a. Budding.* A yeast culture can be made by breaking up a fresh yeast cake, which contains thousands of yeast plants, and mixing it with water and a little sugar. If, the next day, you examine a drop of the culture with a microscope, you will probably observe some yeast cells with knoblike growths on their sides (illustration, p. 431). These growths are buds. When a bud is mature enough, a wall develops between it and the parent cell. Then the bud may or may not break away from the parent cell, but in either case it grows to maturity and thereafter lives its own independent life.

Among the lower plants and animals budding is a common method of vegetative reproduction, or vegetative propagation. It occurs also in some metazoans, including even a few of the simplest chordates.[2]

b. Producing young plants by growth from leaves. Are you familiar with the plant known as "hen and chickens"? It is a popular rock-garden plant, and sometimes is made to grow out of holes cut in barrels filled with soil. Young plants develop in notches around the edges of the leaves. When sufficiently mature, they drop off, take root in the soil, and become new plants.

The walking fern (illustration, p. 431) gets its name from its method of vegetative reproduction. Wherever one of its leaves rests upon the ground, a new fern plant begins to grow from it.

c. Producing young plants by growth from stems.[3] A bulb is an under-ground stem which consists of a short stem surrounded by fleshy leaves containing stored energy food.[4] Gladiolus, daffodil, crocus, and many other familiar flowering plants that grow from bulbs develop small, new bulbs on or within the parent bulb. Lilies produce bulbs at the points where leaves join the stems (illustration, p. 431), as well as on the under-ground bulb from which the plant is growing. Every new bulb has a bud,

[1]*Zoospore* (zō'ō spōr).

[2]Page 537.

[3]There are three different kinds of under-ground stems, besides bulbs—namely, corms, tubers, and rhizomes (rī'zōmz). You may enjoy finding out how they differ, as a "Topic for Individual Study" or as a topic for a report to be made in your science club.

[4]Page 172.

Asexual reproduction by vegetative reproduction · In what respects are the three processes fission, asexual-spore formation, and budding alike, and in what respects does each process differ from each of the others? In what respects are all the methods of vegetative reproduction alike?

which, under favorable conditions, grows into a plant, usually during the following year.

Iris, quack grass, creeping-bent grass, and many other plants have under-ground stems (rhizomes[1]) that grow parallel to the surface of the ground. These plants send up leafy shoots from buds that develop at enlarged points (or nodes[2]) along their under-ground stems. The common potato is an underground stem (tuber[3]), with a bud in every "eye." Perhaps in the spring you have observed that shoots, which are young plants, sprout out of the eyes of potatoes that are in storage.

[1]Footnote, p. 430. [2]*Node* (nōd).
[3]*Tuber* (tū'bẽr).

If a grape-vine or the stem of a rose-bush rests upon the ground, it takes root where it touches, and a new plant develops there. Strawberry plants have special stems, called runners (stolons[4]), that grow above the ground and parallel to its surface (illustration, p. 431). Young strawberry plants develop at certain points (nodes) on these runners.

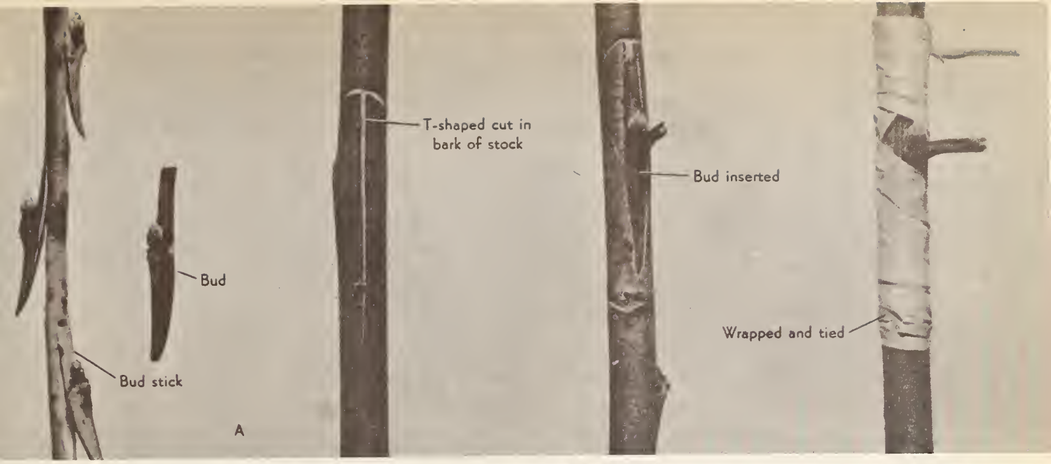
Usually, after a young grape, rose, or strawberry plant has become established, the part of the stem that connects it with its parent dies. The young plant then lives as an independent individual.

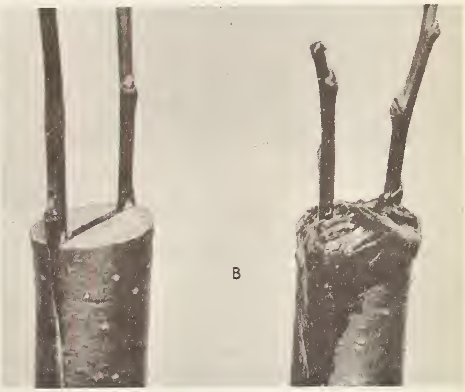
d. Producing young plants by growth from roots. Shoots that are capable of developing

[4]*Stolon* (stō'lŏn).

Every navel-orange tree now in existence was produced, directly or indirectly, from one original parent tree. Can you explain this statement?

California Fruit Growers' Exchange





Steps in making (*A*) a bud graft and (*B*) a cleft graft. Bulletin-Board Display: Make drawings to show other methods of grafting, such as whip, side, and saddle grafting

Hugh Spencer

into mature plants spring up from the roots of Canada thistle, silver poplar, and many other plants.

CONTROLLING VEGETATIVE REPRODUCTION · **In plants.** Plant-growers cause vegetative reproduction to take place as a means of obtaining young trees and other flowering plants of desired kinds. They cut off shoots and sections of branches and under-ground stems bearing buds. Usually they bury the cut ends in sand or soil, or leave them in water long enough for the parts to regenerate[1] roots. They lay branches of grape-vines, rose-bushes, and other plants that can be similarly propagated, along the ground and cover them at intervals with soil. Each covered part develops a young plant. These young plants, when cut away from one another, are ready for transplanting. Growers break off geranium and coleus leaves from their stems and stick the broken ends into moist sand or soil. Soon complete new plants develop.

The grafting of plants is an application of scientific knowledge of plant regeneration.[2] When an unusually fine tree is found or is developed, new trees like it can be produced in great numbers by grafting twigs from the

[1]Page 201.

[2]Page 201.

desirable plant upon the stems of strong but less desirable species (illustration, p. 432).

In grafting, the cambium[1] of the stem and that of the twig must be fastened securely together, so that, as the cut tissues are regenerated, they will grow together (illustration p. 433). Doing this ensures that the vascular[2] system of the stem will continue through the twig and thus will enable the sap to be distributed throughout the entire plant.

In animals. If sponges, hydras, flatworms, starfish, and some other invertebrates are cut into pieces, practically every piece will ordinarily regenerate a complete new animal. Sponges are propagated from cuttings in much the same way as plants are, by the "planting" of small pieces in shallow ocean water.

SUMMARY · [E]Asexual reproduction, or reproduction by a single parent, is accomplished (1) by the division of cells, as in (*a*) fission and (*b*) asexual-spore formation; (2) by vegetative reproduction, as in (*a*) budding and (*b*) the propagation of young plants from (1) leaves, (2) stems, or (3) roots. Man propagates desirable plants artificially by controlling vegetative reproduction.

2. What Are the Methods of Reproduction by Two Parent Organisms?

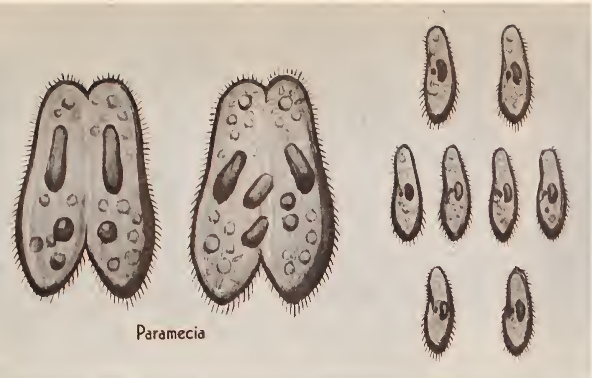
Woodruff,[3] a noted American biologist, experimented with one culture of paramecia for more than twenty years. During that time the animals produced more than twelve thousand generations by fission.

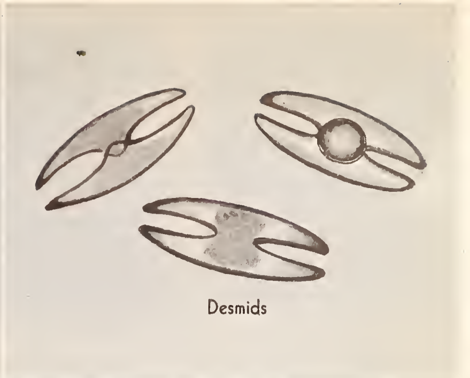
It is most unusual for fission to be repeated through so many generations. Usually paramecia reproduce by that method for about three months. By that time they seem to have lost their vigor. They divide less and less often, and each time that one does divide, the resulting animals, when fully developed, are smaller than their parent. Then pairs of them conjugate[4] (illustration, p. 435). If they are prevented from doing so, they die. Conjugation*[5] restores them to health and vigor, though scientists do not yet know why it does. After conjugation the animals grow to normal size and reproduce again by fission.

Every day Woodruff made some changes in the culture in which the paramecia lived. Apparently doing this prevented the animals from conjugating, as, under normal conditions, they would have done.

SEXUAL REPRODUCTION BY CONJUGATION · **As in single-celled animals and plants.** Conjugation is the simplest method of sexual reproduction. It consists of the uniting of parts or all of two similar cells. It is carried on by many kinds of single-celled plants and animals besides paramecia. You may be able to observe it by examining with a microscope the living things in a drop of a culture made as suggested on page 40. You may see two paramecia attached to each other, side by side. You may observe, also, two crescent-shaped green algae (desmids)[6] similarly attached.

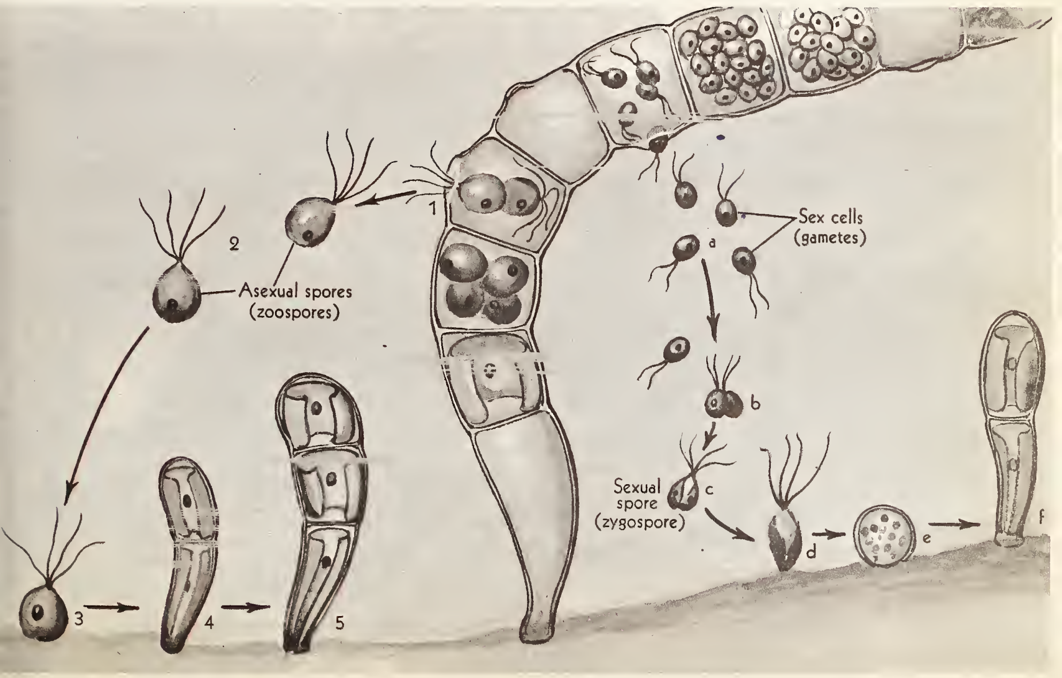
[1]Page 161. [2]Page 153.
[3]Born, 1879. [4]*Conjugate* (kŏn′jo͝o gāt).
[5]*Conjugation* (kŏn jo͝o gā′shŭn).
[6]Page 555.

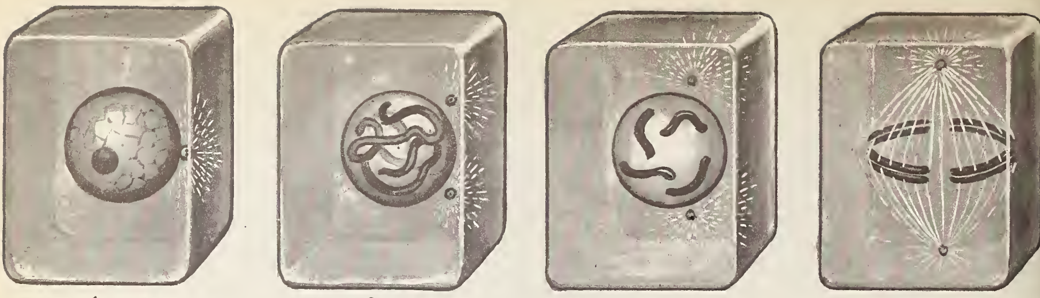




Conjugation by one-celled organisms · The conjugation of the two paramecia finally results in eight individuals. That of the two desmids results in just one cell, a spore. This cell, like each of the eight paramecia when fully grown, divides by fission to form two, and this process is repeated from time to time as before conjugation. The illustration on page 555 shows the conjugation of *Spirogyra*. How are the conjugation of the desmids shown here and that of *Spirogyra* similar?

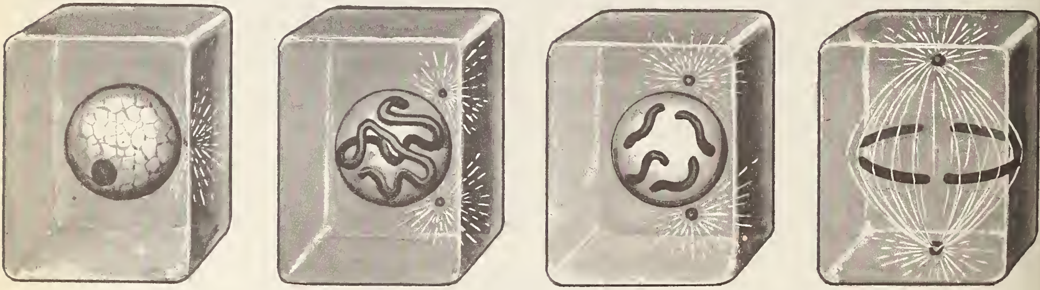
Stages in the asexual reproduction (1, 2, 3, 4, 5) and the sexual reproduction (a, b, c, d, e, f) of *Ulothrix* · How many cilia does one of these asexual spores have? one of these gametes? a sexual spore formed by the union of two of these gametes?





1 2 3 4

The stages in the process of



1 2 3 4

The stages in the process of

At which stages in the two processes as shown here do differences begin to be evident?

with one another and with the parent. Those produced by sexual reproduction

The top illustration on page 435 shows some of the many stages in the conjugation of one kind of protozoan and one kind of alga. As is indicated here, the stages differ with different one-celled organisms. Always, however, one or more cells[1] result, from each of which, if the conditions are favorable, one or more organisms like the two parents will develop. Such cells differ from asexual cells in being produced by the union of two cells instead of by the division of one, as in the two methods of asexual reproduction, fission, and asexual-spore formation.

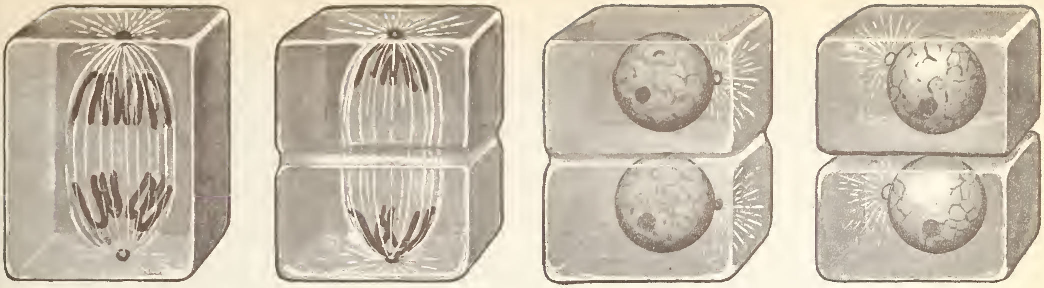
As in a many-celled alga. *Ulothrix*[2] is a bright-green alga that grows in slender filaments. Its habitat is clear running water. Like many other simple organisms, this plant has two methods of reproduction. It reproduces by asexual spores resulting from cell division, in a way somewhat similar to that described on page 428. It also reproduces by sexual spores resulting from conjugation (illustration, p. 435, bottom). Its sexual reproduction takes place thus:

In some cells the nucleus divides to form new cells in much the same way that the asexual spores are formed. These are sex cells, or gametes.[3] When mature, they escape from the parent cells. When, in swimming about, one comes in contact with another,

[1]Cells produced by the conjugation of algae are called sexual spores. Those produced by the conjugation of protozoans are called daughter cells.

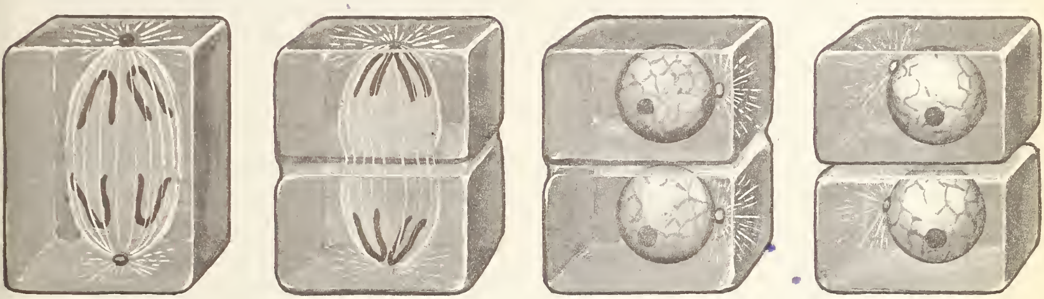
[2]*Ulothrix* (ū′lō thrĭks).

[3]*Gamete* (găm′ēt).



5 6 7 8

forming body cells (mitosis)



5 6 7 8

forming sex cells (meiosis)

The offspring produced by asexual reproduction are always likely to be almost identical
may be considerably different both from one another and from the parent. Explain

from another filament, the two unite and form a sexual spore (zygospore[1]).

This spore swims about for a while, then sinks to the bottom. After a resting period, if conditions are favorable it grows into a new filament of *Ulothrix*. How growth occurs is illustrated above (mitosis) and is explained later.

SEXUAL REPRODUCTION BY FERTILIZATION · [E]As the examples just given show, sexual reproduction by conjugation results from the combining of two cells that are *alike* in size and behavior. Sexual reproduction is brought about more commonly, however, by the combining of two cells that are *not* alike in either size or behavior. Such a union of unlike gametes is known as fertilization.**[2]

[1]*Zygospore* (zī′gō spōr). [2]*Fertilization* (fûr tĭ lĭ zā′shŭn).

In fertilization the male gamete is nearly always a minute, active sperm cell, and the female gamete a relatively large, stationary egg cell. In most cases the sperm swims to the egg, unites with it, and thus fertilizes it. A fertilized egg is the first stage in the development of an embryo.

Egg and sperm cells are developed in separate sex organs. Many plants and animals are both male and female. Each individual has both male and female sex organs.[3] Some organisms—for example, most kinds of hydras—

[3]Such plants and animals are said to be *bisexual* (bī sĕk′shōō ăl) or *hermaphroditic* (hûr măf rō dĭt′ĭk). They are called *hermaphrodites* (hûr măf′rō dīts). The kinds of organisms of which the individuals are either male or female are said to be *unisexual* (ū nĭ sĕk′shōō ăl).

are both male and female. They have both testes,**[1] or male sex organs, which produce sperms, and ovaries,**[2] or female sex organs, which produce eggs, but only for part of the time. For the rest of the time they have no sex organs and hence are without sex.

A small number of animals, including the oyster, are male at one stage of their development and female at another. Most of the higher invertebrates and all the vertebrates, however, are always either male or female. So, also, are some of the higher plants, such as date, holly, yew, and bittersweet.

As in an earthworm. Most of the invertebrates and all the vertebrates have complex sexual organ-systems. Every earthworm, for example, has two ovaries and four testes. It has also four small cavities, or sperm pockets, between its head and the swollen region, or girdle (clitellum[3]).

Two worms with mature sex cells attach themselves to each other, and each fills the four sperm pockets of the other with sperms. They then separate. The girdle of each becomes covered with a slimy secretion. This hardens, forming a skin-like band. The movements of the worm cause this band to slip forward. As it passes the openings of the tubes leading from the ovaries, a number of eggs pass into it. Next sperms that have been placed in the sperm pockets by the other worm empty into it and fertilize the eggs. As the band slips off the head, its ends close, and it becomes a cocoon about a quarter of an inch long. It remains in the ground, and by the time the young worms have hatched from the eggs, its walls have dissolved and the young worms are set free.

As in a vertebrate. The typical male vertebrate has two testes, and the typical female vertebrate two ovaries, though the adult female bird has only one. The method by which male fish fertilize the eggs by depositing sperms over them where they are laid in shallow water is described in another part of this book.[4] The male frog, toad, or other amphibian deposits sperms directly upon the eggs at the instant when they pass out of the female's body while being laid. The male reptile, bird, or mammal, or the male arthropod,[5] deposits sperms directly in the body of the female. Each egg is fertilized by a single sperm.

CELL DIVISION · **In growth, or the production of body cells (mitosis[6]).** The processes of growth and reproduction in higher plants and animals are in some respects alike (illustration, pp. 436–437). Therefore both are described here for convenient comparison.

An organism or one of its parts, such as a leg or a root, grows larger not because its cells increase in size, but because they increase in number. Such an increase in the number of cells results from cell division by the process of mitosis. In mitosis a cell goes through certain stages of development (illustration, pp. 436–437), and finally divides to form two new daughter cells.[7]

In one stage of the process of mitosis (illustration 4, p. 436) the rod-like bodies,

[1]*Testes* (tĕs′tēz); singular, *testis* (tĕs′tĭs).

[2]*Ovary* (ō′vȧ rĭ).

[3]*Clitellum* (klĭ tĕl′ŭm).

[4]Page 136. [5]Page 527.

[6]*Mitosis* (mī tō′sĭs).

[7]*Optional Material.* The various stages of the process of mitosis follow. The numbered cell diagrams at the top of the illustration on pages 436–437 represent, respectively, these stages:

1. A resting cell. The chromatin (krō′mȧ tĭn) forms in a network inside the nucleus.

2. (Early Prophase.) The chromatin forms a long thread, or spireme (spī′rēm), somewhat like a loosely coiled length of yarn. The centrosome (sĕn′trō sōm), near the nucleus, divides and the two halves move apart.

3. (Late Prophase.) The two small bodies move

called chromosomes,*[1] split lengthwise. Half of each chromosome goes to each daughter cell and becomes a whole new chromosome, like the one of which it was a part. Hence each daughter cell has a set of chromosomes exactly like those of the mother cell from which it was formed.

The number of chromosomes in every body cell of plants or animals of the same kind is always the same. For example, the body cells of grasshoppers always have twelve chromosomes each; those of onions, sixteen; of mice and frogs, twenty-four; and of human beings, forty-eight. The upper eight diagrams on pages 436–437 represent cell division in one of the roundworms, which has four chromosomes in each of its body cells.

In the formation of sex cells, or gametes (meiosis[2]). The process by which gametes, or sex cells, are formed is also one of cell division. In its earlier stages it is like the process of mitosis. The chromosomes, however, do not split lengthwise, as in mitosis. Instead, they become arranged in pairs. The chromosomes of each pair separate.

to opposite ends of the cell, where they become the "poles" (asters, ăs'tẽrz). The chromatin divides into short, thick sections, called chromosomes.

4. (Metaphase.) The chromosomes become arranged in the way indicated. Each chromosome splits lengthwise into two parts exactly alike. As a result, there are now as many pairs of exactly similar chromosomes in the cell as there were single chromosomes during the preceding stage.

5. (Anaphase.) One from each pair of chromosomes moves rapidly toward each pole of the cell.

6. (Early Telophase.) The two sets of chromosomes collect at the two poles. The cell begins to divide in two.

7. (Late Telophase.) The two daughter cells develop. The nucleus of each becomes like the nucleus of the original cell. The cell divides in two.

8. (Interphase.) These two daughter cells become growing cells, like the original one.

[1]*Chromosome* (krō'mō sōm).

[2]*Meiosis* (mī'ō sĭs).

In the formation of sperms one chromosome of each pair moves to one end of the cell, and the other to the opposite end. Consequently each of the two new daughter cells formed has only half as many chromosomes as the mother cell had. These daughter cells finally form four sperm cells. But each of these sperm cells has only half as many chromosomes as the original cell had and as all the other body cells have.

In the formation of an egg cell the chromosomes become arranged in pairs, and the chromosomes of each pair separate, as they did in the formation of sperms. At the end of the process, however, only one egg cell is formed. But this egg cell has only half of the chromosomes that were in the original cell. During the process the rest go outside the cell and break up.

The process which reduces the numbers of chromosomes, as in the formation of gametes (sperms and eggs), is known as reduction division (meiosis).

Fertilization. Later, in the process of fertilization, a sperm and an egg unite. The fertilized egg therefore has the normal number of chromosomes, that is, the number found in every body cell of the particular kind of organism. Half of these have come from the male parent and half from the female. For example, a body cell of any onion or any rat has sixteen chromosomes. Each sperm cell and each egg cell of either the onion or the rat has eight. When an egg and a sperm of either of these organisms unite, the resulting fertilized egg has sixteen chromosomes.

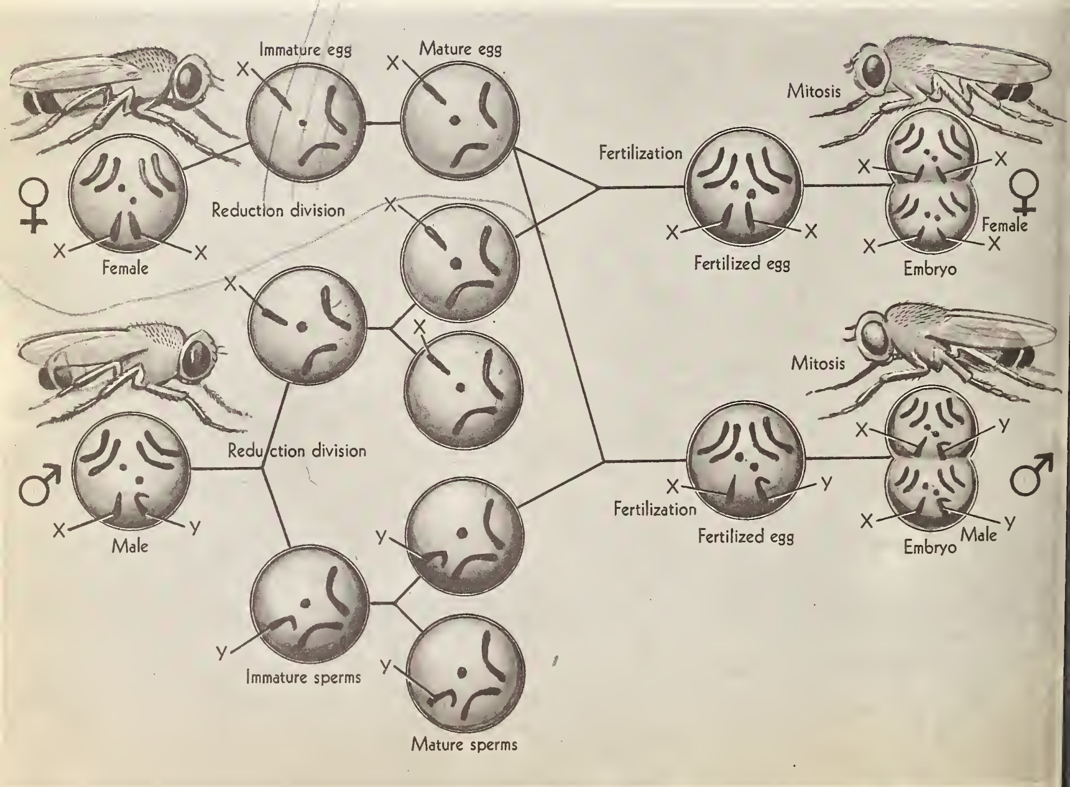
How sex is determined. As has just been stated, every cell of a plant or an animal has in its nucleus two sets of paired chromosomes. One set has been received from one parent cell, the other from the other parent cell. In the organisms that have separate sexes, the

chromosomes of only one of these pairs are the sex-determiners. For example, only one of the four pairs of chromosomes in a cell of the fruit fly is concerned with sex (illustration below.

Whether a young plant or animal is a male or a female is a matter of chance. Though there are some variations in the pairs of chromosomes that determine sex in different organisms, the following description and the illustration on this page outline the most common method by which males and females are formed:

In the every cell of a female the two sex-determining chromosomes are alike and are known as X chromosomes. In the cell of a male they are not alike. One is an X chromosome, like the two in a female cell, and

Fruit flies are small insects that you have probably seen around almost any kind of fruit, especially in the autumn. After you have read pages 441 and 442 carefully, can you explain this diagram, which shows how males and females are formed?
Bulletin-Board Display: In some insects the body cells of the male contain only one sex-determiner (Y); those of the female contain the usual pair of X chromosomes. The sperms formed by reduction division may have X chromosomes, but can have no Y chromosomes. Can you make a series of diagrams, similar to these, which show how the male and the female insects are formed?



Post-Dispatch, from Black Star

Girls have slightly better chances of growing up and of reaching old age than boys. How does this situation tend to result in equal numbers of men and women?

the other is known as a Y chromosome. When eggs and sperms (gametes) are formed by the process of reduction division,[1] the chromosomes of every pair separate (illustration, p. 440). One goes to each sex cell formed. Hence every egg cell must have in it one X chromosome, since female sex cells have X chromosomes only. Each sperm produced by the male, however, may have either an X or a Y chromosome.

If the sperm that happens to unite with an egg is one that has an X chromosome, then the fertilized egg (zygote)[2] will have two X chromosomes. Consequently the offspring that develops from it will be a female. If the sperm that happens to fertilize the egg has a Y chromosome, then the resulting cell (zygote) will have an X chromosome and a Y chromosome. Hence the offspring into which it develops will be a male.

[1]Page 439. [2]*Zygote* (zī′gōt).

Proportions of males and females. The numbers of sperm cells having the X and the Y chromosome are, of course, equal because one with X and one with Y are always formed at the same time. It should therefore be reasonable to expect that the numbers of male and female mammals in any generation would be equal because the chances are even that a fertilized egg will develop into a male or a female. Yet for some reasons not yet known, slightly more males than females are born among human beings. For example, in ordinary times, about one hundred and five boy babies are born for every hundred girl babies (illustration above). In war-time, however,

the proportion of boy babies is somewhat higher. One hypothesis[1] that has been proposed to account for this fact is that in wartime both the marriage rate and the birth rate are increased, and that, for reasons unknown, the first child in a family is more often a boy than a girl.

Recent experiments with rats have shown that the number of males in a generation may be affected by the proportion of protein in the diet of the females before the young are born. This result, however, is merely indicated, not proved. It is believed likely that temperature and other factors may also affect the ratio of males to females. Nobody knows. No way has yet been discovered, or may ever be discovered, of controlling the sex of offspring.

3. What Are the Characteristics of Reproduction by One and by Two Parents, Alternately?

You have probably heard the old saying "Like father, like son." This saying means that a child will be like its parents. The offspring, or young, of higher animals and of most of the higher plants are like their parents in appearance. A young evergreen tree or a puppy, for example, looks enough like its parents so that you know at a glance that it is an evergreen or a dog. But many young plants and animals do not resemble their parents. To illustrate: A caterpillar has no apparent resemblance to an adult moth or butterfly. A tadpole does not look at all like a frog or a toad. Yet by the time these young insects and amphibians have completed their development, they look like their parents (illustrations, pp. 181 and 458.

ALTERNATION OF GENERATIONS · Some kinds of invertebrates and many kinds of plants have alternation of generations. This means that an asexual phase of reproduction in one generation is followed by a sexual phase in the next. Hence these plants and animals never resemble their parents during their entire lives. Instead, they resemble the members of the generation that preceded their parents, or, in other words, their grandparents.

In a simple animal. *Asexual phase.* On rocks and on other objects under water along the ocean shore are numerous dull-white or light-brown patches. A closer examination reveals that these patches are forests of minute "trees" with many thread-like branches. When examined with a microscope, one of these "trees" looks like the illustration on page 443.

Growing on the ends of all the branches are two kinds of structures (polyps[2]). One kind looks somewhat like a yellow hydra in a glassy cup. The other looks like a transparent vase containing a stalk covered with flowers in different stages of development, with the most completely developed ones nearest the mouth of the vase.

Each separate "tree" (hydroid[3]) is a colony of animals. The hydra-like structures on the ends of the branches are the animals themselves. They do not reproduce, however. Each can capture and digest food. Surplus food, which the individual animals do not need, is distributed through the branches, which are hollow and filled with a fluid. This

[1]Page 571.

[2]*Polyp* (pŏl'ĭp). [3]*Hydroid* (hī'droid).

is kept moving by cilia. Thus it transports food to all parts of the colony in somewhat the same way that blood distributes food to all the cells throughout a higher animal's body.

The vase-like structures reproduce by budding.

Sexual phase. The saucer-like buds produced by the asexual phase mature, break off, turn over, and swim away as tiny jellyfish. These jellyfish[1] (medusae[2]) have sex. They are either males or females. Eggs laid by the females are fertilized by sperms from the males. From a fertilized egg a tree-like colony develops, which has food-getting and reproductive individuals like its grandparent.

Thus the fixed, tree-like colony reproduces asexually by budding. Its offspring, the free-swimming jellyfish, reproduce sexually by a union of sperms and eggs. The asexual generation, or phase, of the life cycle produces the sexual generation. The latter produces the former.

In a moss plant. *Asexual phase.* You have probably seen the slender stalks without leaves, and each with a pod-like structure at the top, growing out of patches of moss (illustration, p. 444). This pod-like structure is a spore case. Many small, round spores are formed in it by a process of cell division. This process is somewhat like that by which asexual cells are formed in simpler organisms,[3] as already described. When the spores are mature, they are released and are carried by the wind, often to great distances.

Sexual phase. The spores that happen to fall on moist soil or other suitable spots develop a filament on the ground. This filament is the beginning of the sexual phase (gametophyte[4] phase) of the moss plant. In

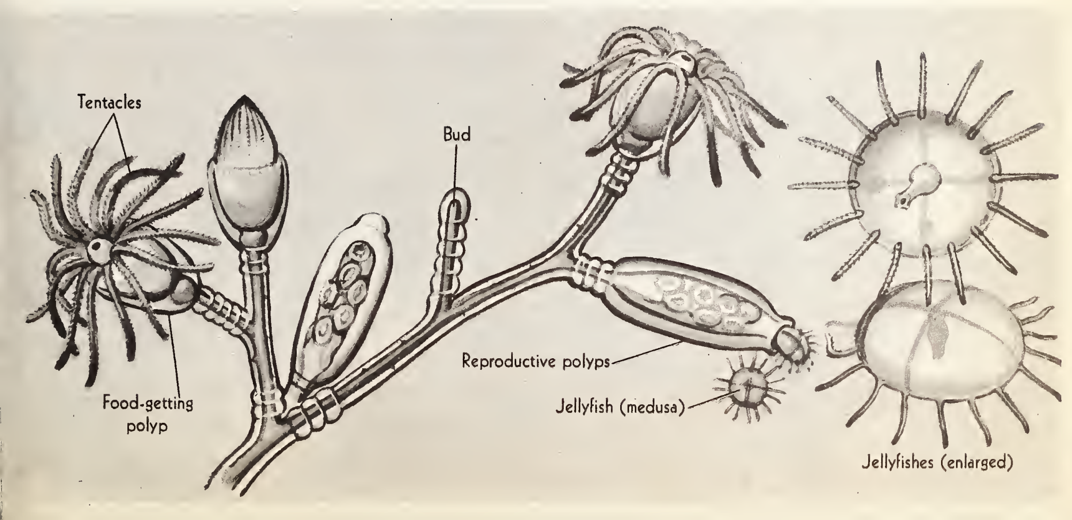
[1]Pages 517–519.

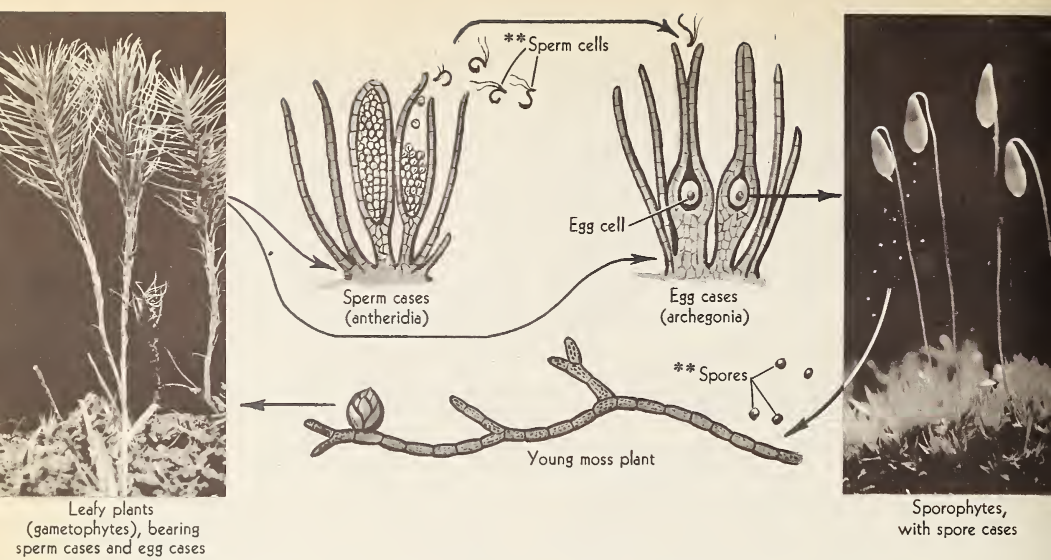
[2]*Medusae* (mē dū'sē); singular, *medusa* (mē-dū'sȧ).

[3]Page 428.

[4]*Gametophyte* (gȧ mē'tō fīt).

Alternation of generations in a jellyfish · **Correlating Biology with English:** Look up in an encyclopedia or a book of mythology the stories of Hydra and Medusa. To what characteristics of the tree-like animal (hydroid) and the jellyfish (medusa) do you think these two forms owe their names?





After studying the text, can you explain these drawings of the life cycle of moss?

its earlier stages it looks like a branching green alga. Root-like structures develop, buds appear, and leafy shoots grow upward from the buds (illustration above). These shoots are moss plants.

At the tops of some of the shoots, or at the ends of their branches, groups of pod-like organs develop. These are sperm cases (antheridia[1]), or male sex organs. Multitudes of minute sperms with flagella are formed in them. At the tops of some of the shoots, or at the ends of their branches, groups of vase-like organs also are formed. These are egg cases (archegonia[2]), or female sex organs. One relatively large egg is formed in each.

When mature, the sperms escape from the sperm cases. Rain or dew on the plant surfaces supplies the moisture in which the sperms swim. When one comes near an open egg case containing a ripe egg, it is believed to be attracted by a chemical substance produced in the top of the egg case. Several sperms thus attracted may swim down the open neck of the egg case to the egg. Usually, however, only one bores through its wall and fertilizes it.

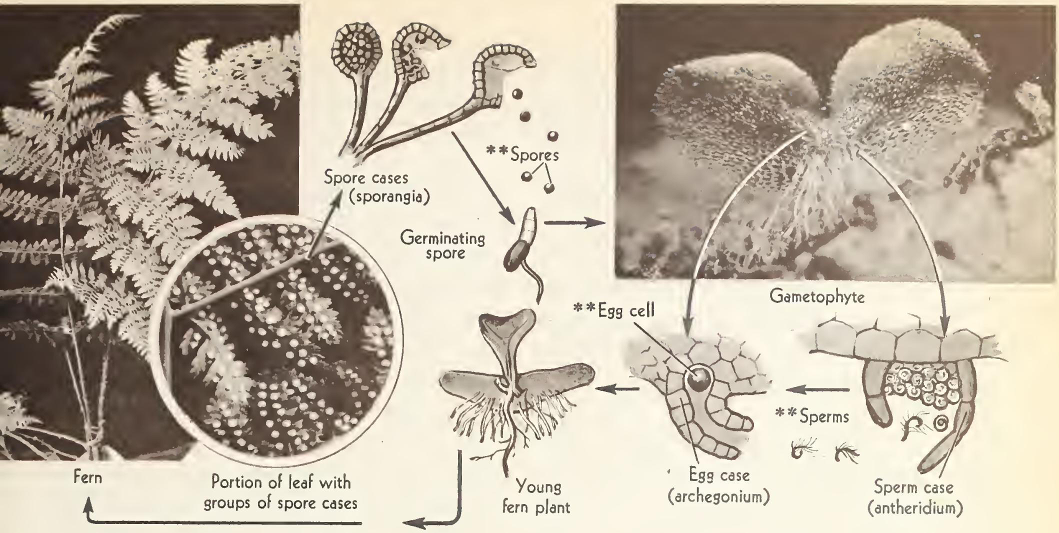
Asexual phase. Instead of falling to the ground and sprouting there, the fertilized egg remains where it is. It begins to grow into a new plant. This new plant (sporophyte[3]) has some chlorophyll and consequently makes part of its food, but it absorbs most of its nourishment from the parent shoot. Hence it is a parasite on the parent plant. It sends up one of the familiar thin, leafless stalks. A spore case develops on its top (illustration above). Thus the life cycle is completed.

In a fern plant. *Asexual phase.* If you have roamed through the woods or parks where ferns grow, you may have observed small, round bodies on the under-sides of the

[1]*Antheridia* (ăn thẽr ĭd′ĭ ȧ); singular, *antheridium* (ăn thē rĭd′ĭ ŭm).

[2]*Archegonia* (är kē gō′nĭ ȧ); singular, *archegonium* (är kē gō′nĭŭm).

[3]*Sporophyte* (spō′rō fīt).



Hugh Spencer

After studying the text, can you explain these drawings of the life cycle of fern?

fern leaves (illustration above). These are clusters of spore cases (sporangia[1]). Asexual spores develop in them in much the same way that they develop in moss plants. When the spores become mature, the cases spring open and throw the spores into the air. Like the moss spores, these fern spores are distributed widely by winds.

Sexual phase. When one of these spores settles on moist soil or in some other suitable place, it begins to grow. It develops into a little round or heart-shaped plant (gametophyte), consisting of a single leaf about a third as big as a dime.

Male and female sex organs develop chiefly on the underside of this plant (illustration above). These are (1) sperm cases (antheridia), which produce numerous sperms with cilia, and (2) egg cases (archegonia), which produce one egg each. The sperms, when mature, are released from the sperm cases. They swim vigorously on any film of moisture that covers the surface of the plant. When one of them reaches an egg, it fertilizes the egg.

Asexual phase. The resulting embryo immediately begins to grow. For a while it is a parasite on the parent plant. Soon, however, it grows roots in the soil, and also a stem and leaves, which make its food. Thus it develops into the familiar fern plant (sporophyte) with which this description began.

SUMMARY · [E]Thus ferns and moss plants have alternation of generations. The life cycle of each consists of two phases, a sexual and an asexual phase. In the sexual phase (the gametophyte phase) a plant with sex organs producing sperms and eggs grows from an asexual spore. In the asexual phase (the sporophyte phase) a plant that develops asexual spores grows from an egg fertilized by a sperm.

[1]*Sporangia* (spō răn′jĭ *ȧ*); singular, *sporangium* (spō răn′jĭ ŭm).

FLOWERS · The flowering plants are familiar to all of us. Yet there are many flowers that few people ever "see," because the flowers are too small, because they are not conspicuous, or because they do not have the usual appearance of flowers.

One needs a microscope in order to learn much about the white flowers of the duckweed, a minute floating plant common on our ponds and streams. Most people never think of the grasses and of the small grains as being flowering plants, because they have never noticed their small blossoms. Not many people know that the tassel on the top of a corn plant and the "silk" on the ear are flowers. Have you ever "seen" the bloom of the poinsettia, the familiar Christmas plant? What you no doubt have observed, and have probably thought was the flower, was the royal cluster of red leaves that surrounded the real flower.

Have you ever examined with a hand lens the bloom of a calla lily, a dandelion, or a daisy? What appears to be the blossom of the calla lily is the striking white or colored structure that grows around the central structure. The real flowers are very small ones, which grow in great numbers on the spike. The real flowers of the dandelion, the daisy, and others of the great group (Compositae[1]) of flowering plants to which they belong are small, too. What appears to be one flower of such a plant is made up of a great cluster of these small blossoms.

In contrast with the flowers that often escape notice are those of many tropical plants. These are commonly larger and far more striking and beautiful than the blossoms of plants of the Temperate Zones. One example is the gorgeous, many-colored blossom of a plant (*Rafflesia*[2]) that grows in the jungles of the islands between Malaya and Australia. Sometimes this flower is three feet across and weighs fifteen pounds.

[1]*Compositae* (kŏm pŏz'ĭ tē).
[2]Page 563.

THE FLOWER STRUCTURES · In order to understand alternation of generations in a flowering plant, it is necessary first to study flower structures.

The flowers of various plants[3] differ in many respects. They are nevertheless alike in that they all contain sex organs. The structures of a typical flower are shown on page 447.

If you will examine almost any common flower, you will probably notice first the corolla,*[4] made up of white or colored leaf-like petals.*[5] You may notice also the calyx,*[6] made up of less conspicuous leaf-like sepals*[7] below the corolla. If you pull the petals apart or look down into the flower, you will see the stamens**[8] and the pistil**[9] or pistils. A stamen commonly looks like a stem with a grooved knob at the top. A pistil usually looks somewhat like a bowling pin or a round bottle with a long neck.

The ovary is the enlarged base of the pistil. Inside it are one or more ovules.**[10] A cherry flower or a buckwheat flower has only one ovule. A tobacco flower has several hundred. Ovules are the structures that may later become seeds. Every grain on a ripe corn-cob is a seed that has developed from an ovule.

COMPLETE, PERFECT, AND IMPERFECT FLOWERS · A flower may lack either a corolla or a calyx, but every flower has either stamens or a pistil, or usually both. The stamens and pistils are often spoken of as the male and female reproductive organs, because the

[3]Pages 562–564.
[4]*Corolla* (kō rŏl'ȧ).
[5]*Petal* (pĕtl).
[6]*Calyx* (kā'lĭks).
[7]*Sepal* (sē'păl).
[8]*Stamen* (stā'mĕn).
[9]*Pistil* (pĭs'tĭl).
[10]*Ovule* (ō'vūl).

pollen**[1] from the stamens produces the sperms, and the ovary encloses the ovules.

A flower that has all the usual parts—namely, calyx, corolla, stamens, and one or more pistils—is a complete flower. One that has both stamens and a pistil, even though it lacks calyx or corolla, or both, is a perfect (hermaphroditic) flower. One equipped with either stamens or a pistil, but not both, is an imperfect flower. It is either a male (staminate[2]) or a female (pistillate[3]) flower.

Sometimes imperfect flowers are on the same plant, as on melon, cucumber, and corn. All the flowers at the top of the calla-lily spike are male, since they have stamens but no pistils. All those at the bottom are female flowers because they have pistils but no stamens. Sometimes imperfect flowers are on separate male and female plants, as on asparagus and hop.

ALTERNATION OF GENERATIONS IN FLOWERING PLANTS · Alternation of generations takes place in flowering plants. It is not so readily observed, however, as that in mosses and ferns, because (1) the little male and female plants (gametophytes) of the sexual phase, which produce the sperms and the eggs, never look like an ordinary plant, and (2) both kinds grow, out of sight, inside the pistil of a flower. The phase of the life cycle that is familiar is the asexual phase, which produces the plant (sporophyte) on which the flowers bloom.

Sexual phase. Pollen is produced by cell division in the tips (anthers[4]) of the stamens in somewhat the same way that asexual spores are formed in mosses and ferns. When the pollen grains are mature, the anther splits open and they sift out (illustration, p. 448).

[1]*Pollen* (pŏl′ĕn).
[2]*Staminate* (stăm′ĭ nāt).
[3]*Pistillate* (pĭs′tĭ lāt).
[4]*Anther* (ăn′thẽr).

A flower can be pollinated only by pollen from the same kind of flower or, in a few cases, from a closely related one. Furthermore, the pollen must be deposited upon the tip (stigma[5]) of the pistil during the brief period when the stigma is ready to receive it. When both these conditions are met, the pollen germinates and becomes a male plant. This plant consists only of the pollen grain and the pollen tube that develops from it. It is a parasite of the parent plant (illustration, p. 448).

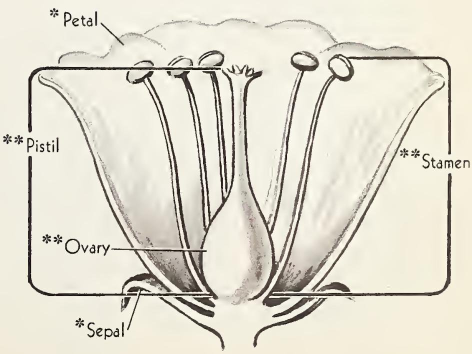
The pollen tube grows down through the stem (style[6]), or neck, of the pistil to any one of the ovules in the ovary. By the time it has extended to an ovule, it may vary in length from about an eighth of an inch in a calla lily to eighteen inches in corn. It may complete its growth in a few hours, as in the case of a bean, or in about a year, as in the case of an oak.

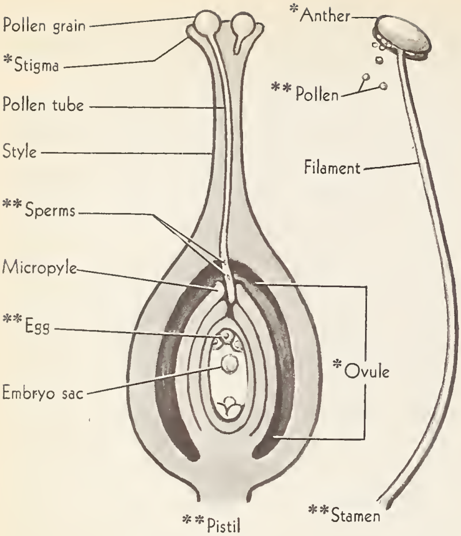
Two sperm nuclei are produced from the pollen-cell nucleus. These move down the pollen tube as it grows.

Meanwhile changes are taking place in the

[5]*Stigma* (stĭg′mȧ). [6]*Style* (stīl).

Parts of a typical flower · Is this a complete or a perfect flower? Explain





Fertilization of a flower · Can you state the function of each structure whose name is double-starred (**)?

ovary. Inside each ovule is a large cell (embryo sac). This cell is a spore. Within it a microscopic egg-producing, or female, plant develops. Like the male plant, this female plant is a parasite of the parent plant. One egg cell is produced by the female plant inside this large cell, as the diagram on this page shows.

When any pollen tube grows long enough to reach this cell, the two sperm nuclei from the tube pass into it. One of them unites with the egg and fertilizes it. The remaining sperm combines with other structures within the large cell.

Asexual phase. The fertilized egg continues to grow as an embryo plant. During the early part of its life this embryo too lives as a parasite. Energy food manufactured by photosynthesis[1] in the parent flowering plant is stored around the embryo. The embryo uses part of this food for its immediate growth. It develops a tiny root, stem, and usually one or two leaves. It grows until the outer ovule wall becomes a dry and hard seed coat. The seed is then ripe. It consists of (1) the microscopic embryo plant, (2) the food which has been stored around the embryo, and (3) the seed coat.

The embryo plant goes through a resting stage before germinating, just as do the sexual spores of the simpler plants already described. Usually, in the following season, when conditions are suitable, it germinates. Then it continues its life as an independent green plant, producing flowers, in which the spores later develop. These spores are, of course, the pollen and large cell within the ovule, already described.

4. *What Are Some Further Adaptations Related to Reproduction?*

[P]All the various kinds of living things go through a life cycle, just as individual organisms do. The early period in the existence of each species of plant or animal may be called its youth. A period of maturity follows, and finally one of old age. During its youth the organism develops, at a relatively fast rate, adaptations which enable it to survive in its environment. During its maturity it develops to the point where it is most successful.[2] In its old age it develops such com-

[1]Page 154. [1]Legend, p. 40.

plex and highly specialized structures that it cannot continue to exist if there are even fairly slight changes in the habitat.

Some species have lived from early youth to old age and have become extinct in a few thousand years. Others, after millions of years of existence, are still only in their youth or maturity.

The failure of almost any organ to function may result in the death of the species that possesses it. But if the reproductive processes of a plant or an animal should fail, it would disappear from the earth almost at once.

Having different methods of reproduction enables various organisms to persist on the earth. Many adaptations for reproduction have already been described. Others will be described in the following pages.

SELF-FERTILIZATION AND SELF-POLLINATION · Self-fertilization[1] occurs in some of the simpler invertebrates whose individuals possess both male and female sex organs. Examples are found among flatworms.[2]

Self-pollination[3] occurs in many plants, including cotton, garden peas, tobacco, and most of the grains except corn and rye. In such plants the pollen and the tip of the pistil become mature at about the same time. Self-pollination is then brought about in different plants by a number of means, including these: (1) The flowers never open. Hence no pollen

[1]*Self-fertilization:* the act or process of fertilizing an egg with a sperm from the same animal.

[2]Page 519.

[3]*Self-pollination* (pŏl ĭ nā′shŭn): the act or process of transferring pollen from stamen to pistil in the same flower.

What flower structures can you recognize here?

Science Service

from another flower can get on the pistil tip. (2) The tops of the stamens are often above the tops of the pistil. Consequently the pollen falls upon the latter. (3) The stamens or the petals grow in such a way that, by the time the pistil is ready to receive the pollen, its tip is touching the tips of the stamens (illustration, p. 451).

CROSS-FERTILIZATION; CROSS-POLLINATION · Cross-fertilization[1] or cross-pollination[2] is the only method possible with animals or plants whose individuals are either males or females. It is the only method possible, also, with most of the organisms whose individuals have both male and female sex organs, because either their structure or certain conditions prevent self-fertilization or self-pollination. As illustrations, the method of reproduction of the earthworm prevents self-fertilization. The gametes from the same *Ulothrix* filament, though they appear to be alike in every way, will not conjugate. The sperms and the eggs are formed on the same hydra; yet they mature at different times. So also, usually, do those formed on the same moss or fern plant.

Among the conditions that prevent self-pollination and make cross-pollination necessary are these: (1) The pollen becomes ripe either before or after the pistil of the same flower is ready to receive it. (2) The pollen from a flower will not germinate on the pistil of the same flower, or, if it does, the resulting seeds produce inferior plants. In a few cases pollen on the pistil of the same flower may even cause the latter to wither. (3) The stamens and pistils grow in various arrangements—for example, at different levels, or with other flower structures between them—which prevent the pollen from falling upon the pistil tip of the same flower (illustration, p. 451).

The agents of cross-pollination are indicated on page 452.

So important to fruit-growers is the pollination of the flowers of fruit trees that recently a new "pollinating industry" has been developed. In California some "bee farmers" make a profitable business of renting to fruit-growers hives of bees for the short time during which the flowers of the fruit trees are being pollinated.

Not only does the keeper receive a fee for the services of his bees, but also he markets the abundant honey which they produce as "hired workers." The fruit-grower is satisfied because he has learned that the extra bee population during pollinating time greatly increases the fruit yield of his trees.

Recently bees have been shipped by airplane from Seattle, Washington, to towns in Alaska, to pollinate the crops, as well as to make honey for the Alaskan farmers.

COMPARISON OF SELF-FERTILIZATION WITH CROSS-FERTILIZATION AND SELF-POLLINATION WITH CROSS-POLLINATION · Self-pollination is more certain than cross-pollination. But there is considerable evidence which indicates that offspring produced by cross-fertilization or cross-pollination are larger, heavier, more vigorous, and more productive than those produced by the other method. Some botanists, however, believe that the disadvantages of self-pollination and the advantages of cross-pollination are smaller than have often been assumed.

Animals that are self-fertilized and plants that are self-pollinated breed true; that is, their offspring are usually almost exactly like them. Animals produced by different parents, and plants that are cross-pollinated,

[1] *Cross-fertilization*: the act or process of fertilizing an egg with a sperm from another animal.

[2] *Cross-pollination:* the act or process of transferring pollen from the stamen of one flower to the pistil of another.

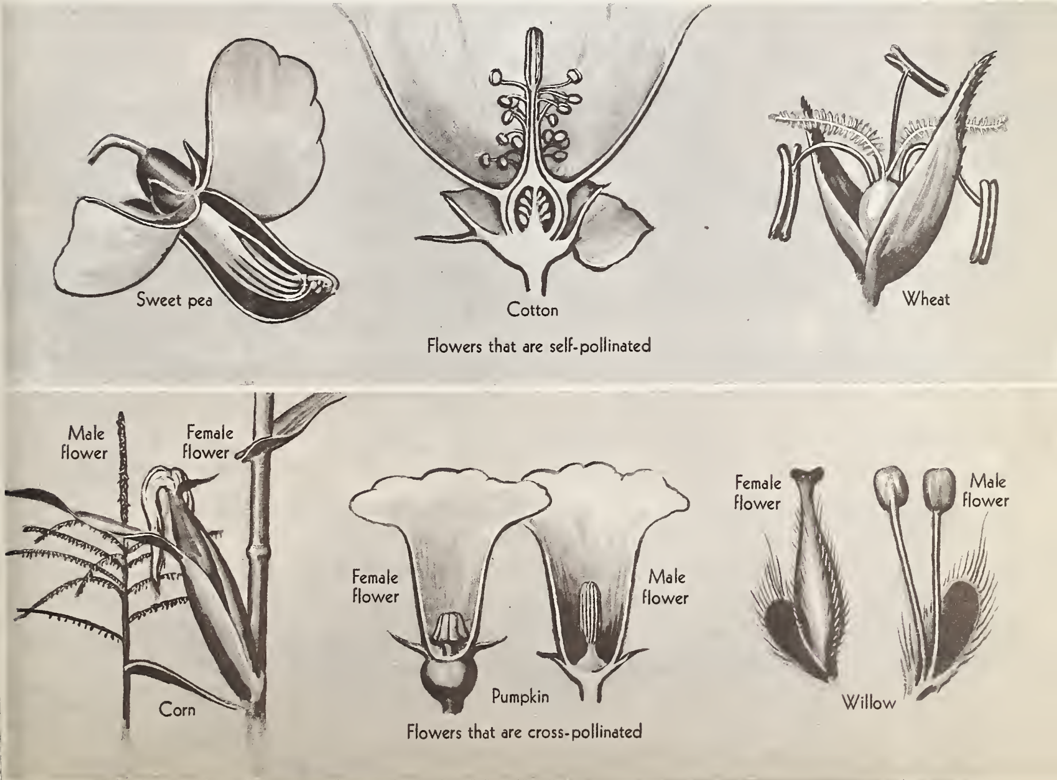
however, are likely to vary considerably from either parent. For example, the puppies of a fox terrier and a cocker spaniel probably will not closely resemble either parent dog. If, moreover, you were to plant a seed from a choice peach tree, the plant that grew from it would not be likely to bear fruit to match that of the parent tree in quality. It is for this reason that plant-growers use methods of producing new plants by regeneration of parts[1] when a superior plant, such as the Burbank potato or the Delicious apple, is found. Of course they grow choice plants of many other kinds from carefully selected seed.

ADAPTATIONS FOR SPREADING TO NEW HABITATS · The chances that a certain kind of organism will continue to exist are increased if it can spread to new habitats. There are various ways by which plants become more widely distributed. They are spread in the vicinity of the parent plants by the various methods of vegetative reproduction. They are spread to more distant localities by chance happenings to their seeds.

Seeds of water plants and of plants that grow on the banks of streams and the shores

[1]Page 201.

Are any of the methods of self-pollination and cross-pollination shown here different from those described in the text? Can you suggest a "Topic for Individual Study" which relates to this illustration and legend, and which might be included in the series "Why Not Become a Naturalist?"?



Science Service

Light pollens are carried from the flower that produces them to another by winds. Heavy pollens are carried by insects (illustration, p. 191), birds, or other animals that enter the flower to get the sweet liquid (nectar) secreted by glands in the flower. The pollen of certain water plants is carried to the pistil tips of other flowers by the water. Why do you think this particular flower is pollinated by the humming-bird rather than by insects or the wind?

of oceans are carried by currents to new habitats. The seeds of many other plants have special structures which function in spreading the plants to new locations (illustration, p. 455).

By being eaten, the fruits of many flowering plants serve indirectly as a means by which the plants gain footholds, often in distant localities. The fruits do not, however, serve this purpose unless they contain seeds. To understand these statements one must know more accurately than most people do what fruits are.

Most people think of a fruit as being something, like a cherry, an apple, or a melon, which has juice and pulp and which contains one or more seeds. To be sure, a cherry, an apple, and a melon are fruits; but so also are a pea-pod, a filbert, an ear of corn, a milkweed pod, and a tomato. A fruit** is a matured, or ripened, ovary and its contents.

There are many variations in fruit structures. A squash or a pumpkin consists of the enlarged ovary of a single flower with a single pistil. A strawberry or a raspberry also is made up of the enlarged ovary of a single flower, but this flower has many pistils. Sometimes the fruit includes, along with the ovary, one or more other flower structures, such as petals, sepals, or the enlarged top of the stalk (receptacle[1]), upon which are the flower parts. A bean-pod, for example, includes the top of the flower stalk with the ripe ovary. Some fruits consist of more than one ovary. A pineapple and a fig are such fruits. Each is made up of the enlarged ovaries of a cluster of flowers.

Cherries, plums, apples, and, in fact, most other fruits contain ripe seeds. But bananas and pineapples do not. Moreover, man is increasing the number of fruits that do not, by propagating seedless fruits, such as seedless grapes, and seedless oranges and other seedless citrus fruits.

Some of the ways in which animals cause plants to gain footholds in new habitats by using their fruits for food are these: Birds and other fruit-eating animals swallow the seeds along with the fruits. The seeds, thus eaten, are protected by their seed coats, and hence usually pass through the animals' digestive systems unharmed. The seeds are deposited at varying distances from where the fruits were eaten. Squirrels and other animals bury nuts in the ground for future food. Later the animals fail to find many of these buried fruits. Hence the seeds inside may grow into new plants. Man is the chief agent in establishing seed-bearing plants by chance in new locations through using fruits as food. The seeds of fruits which he ships all over the world often fall finally on soil where they can grow.

REPRODUCTION FROM UNFERTILIZED EGGS · **By natural processes.** There are a considerable number of flowering plants and a few animals that can produce young from unfertilized eggs. A dandelion is such a plant, and plant lice and bees are such animals. The seeds of the dandelion always develop without fertilization because dandelion pollen, though abundant, does not function.

Plant lice hatch in the spring from eggs that have been laid late in the preceding fall. All these young plant lice are females. In a short time they mature and lay their eggs. Although there are no male plant lice alive in the spring to fertilize the eggs, the eggs hatch nevertheless. But each young louse is a female, like its one parent.

Generation after generation of female plant lice are thus produced during the spring and summer from eggs not one of which has

[1]*Receptacle* (rē sĕp'tȧ kl).

been fertilized. In the fall, however, both males and females hatch from the eggs then laid. The eggs of these females are fertilized by the males. These are the plant-lice eggs that remain on the plants all winter and hatch the following spring. But again the new generation of plant lice which hatch from these eggs are all females (illustration, p. 456).

Some of the eggs that queen bees lay during the summer are fertilized, and some are not. Only females hatch from the fertilized eggs, and only males, or drones, from the unfertilized ones. Sometimes, if the queen of a hive dies, workers will lay a few eggs. But these eggs will not maintain the bee population, for they always produce males.

By artificial means. Scientists have been able to cause unfertilized eggs of some animals to develop by artificial means. Eggs of starfish, sea urchins, and frogs have many times hatched after having been stimulated in various ways—namely, by chemicals, such as acids and salts, by higher or lower temperatures, by electricity, by being shaken, or by being pricked with a needle. In some cases the animals thus produced have grown to maturity. One scientist was even able to cause young rabbits to develop from the unfertilized egg cells of a rabbit.

5. How Is Reproduction Brought About in Higher Animals ?

The reason that many organisms which are abundant have not long since become extinct is that they produce countless numbers of spores, eggs, sperms, or pollen grains. To illustrate: The spores produced by certain algae are sometimes so numerous as to make the water around the plants look green. It is estimated that a liver fluke (a flatworm[1] parasite of sheep, cows, and pigs, and occasionally, also, of man) lays half a million eggs. Among the fish, a female carp lays perhaps half a million eggs, a female turbot about nine million, and a female ling perhaps thirty million! Male sea urchins[2] sometimes discharge so many sperms that the water around them is made cloudy. It is estimated that a single male flower of a corn plant produces fifty million pollen grains. Even among the higher mammals the females have thousands of cells that could develop into eggs, and the males produce millions of sperms.

WASTE OF LIFE · [E]Plants and animals with complex life histories must produce enormous numbers of young. Otherwise not enough of them would "grow up" to keep those kinds of organisms from becoming extinct. Even after a spore or a seed has germinated or a simple animal has been hatched or born, think of the chances against its ever living long enough to reproduce its kind. For example, think how many chances there are that a new-laid egg of a horse-hair snake[3] will not develop into an adult worm and produce young. The egg could fail to be fertilized by a sperm. The egg could be eaten by some water animal. The young larva could fail to find an insect larva for a first host just when it had to find one. This host might die or be killed before it was ready to leave the water. If this were to happen, the young parasite would die, too. The worm, in its protective covering, might not be eaten by a suitable

[1]Page 521. [2]Page 525. [3]Pages 426–427.

Can you name plants, other than the ones shown here, whose seeds are dispersed by winds? Those of the second group catch in animals' fur. Can you name others that are dispersed in this way? To which group does the paradise nut (p. 363) belong?

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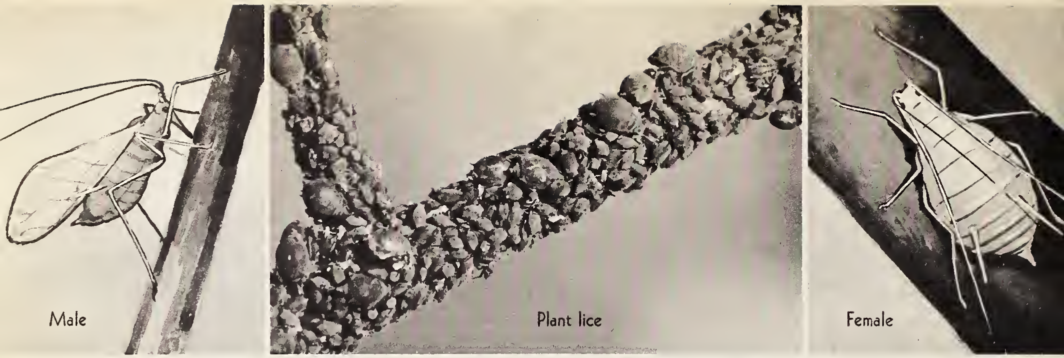
second insect host so that it could continue its parasitic growth. This second host could later fail to fly or hop into the water at just the time when the parasite was ready to leave its body. During any part of its life the horse-hair snake could die of disease.

Any one of these situations would result in the death of the horse-hair snake. It is difficult, therefore, to imagine how any individual worm could just happen to be fortunate in every one of such a long series of occurrences, or, as one high-school student



Plant lice · What season of the year is indicated here? Explain.

phrased it, "to be lucky enough to be at the station every time just when the bus came along." Yet many are. There are millions of horse-hair snakes. Think how many more billions there must have been that never "grew up." The death rate of horse-hair snakes must be so high as to be almost beyond belief.

It is not only the simpler invertebrates that have high death rates. They are found also among most kinds of fishes and many kinds of amphibians, reptiles, and small mammals. For example, in late summer at one spot on the Oregon coast one may see, within an area the size of a city block, young toads as big as a dime in perhaps a dozen patches. Each patch is from a foot square to several feet across, and the toads are often piled several deep in each. Yet in the same locality one does not ever see a noticeably large number of adult toads (illustration, p. 458).

ADAPTATIONS FOR THE SURVIVAL OF SPECIES · Thousands of examples could be found which illustrate the "waste" of life. Nevertheless various organisms, especially the higher chordates, have adaptations of behavior and structure that increase the percentages of their egg cells that are fertilized and that develop into adults.

1. Increased chances that fertilization will take place. Among the plants, except the self-pollinating ones, and among the simpler animals, it is entirely a matter of chance whether or not any eggs will be fertilized. It is so even with most of the fishes.[1] Among the higher vertebrates, however, and even among the insects and other arthropods, the probability that fertilization will take place is much greater because the methods of fertilization are more certain.

2. Protection during the early stages of development. *Simpler organisms.* Even among simple organisms there is some protection of the spores or of the embryos. The spores of plants and animals have walls that afford protection until conditions are favorable for further development. As a result, probably billions of such organisms reach maturity that otherwise would not

The embryos of flowering plants are protected within the ovaries while the seeds are maturing. Also, they are protected by the seed coats until the seeds germinate. The eggs of some spiders are protected within egg cases, woven by the female spiders. The eggs of grasshoppers are laid in holes in the

[1]Page 136.

ground, where they are relatively safe from enemies.

Higher organisms. The embryos of mammals and of some other animals are protected within the females' bodies until they are born. Some are well developed at birth. Others are not. To illustrate: A young garter snake can take care of itself as soon as it leaves its mother's body. A calf, a colt, or a fawn can stand and walk almost as soon as it is born. In contrast, a new-born kangaroo has little resemblance to an adult. Its pink body is only about two inches long. It has well-developed front legs, but no hind legs. It is barely able to crawl into its mother's pouch. There it remains for weeks, taking milk produced by the milk glands, before it has developed enough so that it can venture outside for even a few minutes.

The young of mammals or other animals that develop as embryos in the females' bodies are said to be "born alive" and are called "living young." These expressions are used in order to distinguish such animals from those that are hatched from eggs.[1] *Born alive* and *living young* are, however, confusing expressions, for, of course, the animals that are hatched are alive, too. In fact, an egg cell, the instant that it is fertilized, is just as truly alive as a new-born kitten or a new-hatched chick.

The embryos of such egg-laying animals as turtles, alligators, and birds are protected by a tough or a hard egg-membrane or egg-shell. *Egg*, as used here, has a different meaning from the same word as used earlier in this section. In its scientific use, employed earlier, *egg* means an egg cell, or female reproductive cell. After being fertilized by a sperm, such an egg develops as an embryo if conditions are favorable. In its common use, as in the first sentence of this paragraph, *egg* means a body having a protective covering of membrane, shell, or both, enclosing an egg cell surrounded by stored energy food. If the egg cell in such an egg is fertilized and the embryo develops, the latter consumes this stored energy food as it grows.

The largest known egg is that of the elephant-bird of Madagascar, which became extinct four or five hundred years ago. Its egg had a capacity of more than two gallons, but the egg cell within it was microscopic, like every other egg cell.

3. Parental care. Among the simplest behaviors that can be classed as examples of parental care are these: Female spiders of some species guard their egg cases and their young for a time after the latter have hatched from the eggs. Female crustaceans,[2] such as crayfish and lobsters, carry their eggs and later their young under their "tails," or abdomens. Thus they give their progeny protection, and, by keeping the water constantly moving over them, they supply them with oxygen. Female scorpions carry their young about on their backs, but if any falls off, the mother scorpion devours it. Many insects lay their eggs by instinct[3] in places where there will be food for the larvae: inside the bodies of plants or other animals; on, among, or attached to feathers or hair, or near decaying organic matter. Some of the wasps paralyze spiders and leave them to serve as living prey for the larvae when the latter hatch. Sticklebacks and a few other fishes, some reptiles, practically all birds, and some squirrels and many other mammals build nests for their young. A female Surinam toad carries her eggs and young in pits

[1]Animals that bear their young are called *viviparous* (vī vĭp′*ă* rŭs) animals. Animals that lay eggs, from which their young hatch, are called *oviparous* (ō vĭp′*ă* rŭs) animals.

[2]Page 361. [3]Pages 361–362.

in her back until the latter have passed entirely through the tadpole stage.

The length of time during which the various kinds of young birds and mammals need and receive parental care varies greatly. As a rule, the birds and small mammals mature rapidly and are able to take care of themselves within a few weeks or a few months. Some of the large mammals, however,—namely, gorillas, chimpanzees, elephants, and human beings,—require many years in which to mature. Hence they must have many years of parental care.

SMALL FAMILIES · Birds and mammals have relatively few young. Cows and horses rarely bear more than one offspring at a time. Cats, dogs, and pigs normally have several progeny in a litter (illustration, p. 464). Most of the common birds hatch from two to six eggs. Chickens and ducks rarely have broods of more than a dozen.

In contrast with the young that receive no parental care, such as those of the horsehair snake and the common toad, the offspring of birds and mammals reach maturity in relatively high percentages.

SUMMARY · [E]The kinds of animals that fertilize the eggs in the females' bodies, that have their embryos protected, and that provide parental care are able to persist on the earth, even though they have relatively few offspring.

THE DEVELOPMENT OF A MAMMAL · As in the moss and the fern, so in the mammal, the sperms swim to the ripe egg cell. One bores through its wall and fertilizes the egg. The stages that follow are essentially the same for every animal that grows from a fertilized egg (illustration, p. 460). Some of the simpler invertebrates, however, complete their development without ever reaching the final stages through which higher animals pass.

The life history of the toad · What kinds of enemies do you think might attack the toad during each stage of its metamorphosis?

First, the fertilized egg divides in much the same way that a protozoan reproduces by fission. Then new cells are formed (by mitosis), four, then eight, then sixteen, and so on.

After many cells have been thus produced, they form a hollow ball. Its wall consists of a single layer of cells, and it is filled with a fluid. In this stage (blastula[1] stage) the structure of the embryo is almost the same as that of a volvox (illustration, p. 566).

It continues its development thus: one half of the wall grows and pushes back against the other half. In this way a hollow, open-ended body (gastrula[2] stage) with a two-layered wall is formed. Now the body has the same sort of structure that the adult coelenterates have (illustration, p. 460).

Next it passes into a three-layered stage, similar to the three-layered body form of a flatworm.[3] Certain organs and organ-systems develop from each of the three body layers, as the mammal embryo completes its development. By the time it is ready to be born, it has nearly all its organs in more or less well-developed stages, and it resembles to a considerable extent the adult of its species.

From the beginning of its life the young human being, like every other young mammal, grows as a separate individual. Starting as a microscopic, fertilized egg cell, it increases in size several million times before birth. It develops its own circulatory system, but this is never directly connected with that of its mother. By osmosis food, oxygen, and other necessities pass into its blood from the mother's lymph and blood, which surround it. Wastes pass from its blood into the mother's.

INHERITANCE OF DISEASES · [E]Most diseases are not inherited, though tuberculosis and perhaps some others can be contracted by a baby after birth if its mother has one of these diseases. It is true, also, that most diseases and injuries of the mother cannot affect the developing embryo. But conditions that affect the mother's nutrition can. Also, certain diseases of the blood (for example, syphilis) can be transmitted to the baby before or during birth. For that reason thirty-five states have laws requiring that a marriage license can be secured only after the man or the woman, or both, have been proved by a medical test to be free from venereal diseases.

Checking What You Know

BIOLOGICAL FACTS · (*Do not write in this book.*) **Pages 426–434.** **1.** The most common method of reproduction among the simpler organisms is *sexual* reproduction which involves *only one* parent.

2. When fission occurs, the cell divides into *many spores*, each of which may develop into an adult organism.

3. In *budding* and *asexual-spore formation* the parent organism no longer exists.

4. Name the kinds of plant structures with which or on which vegetative reproduction may occur.

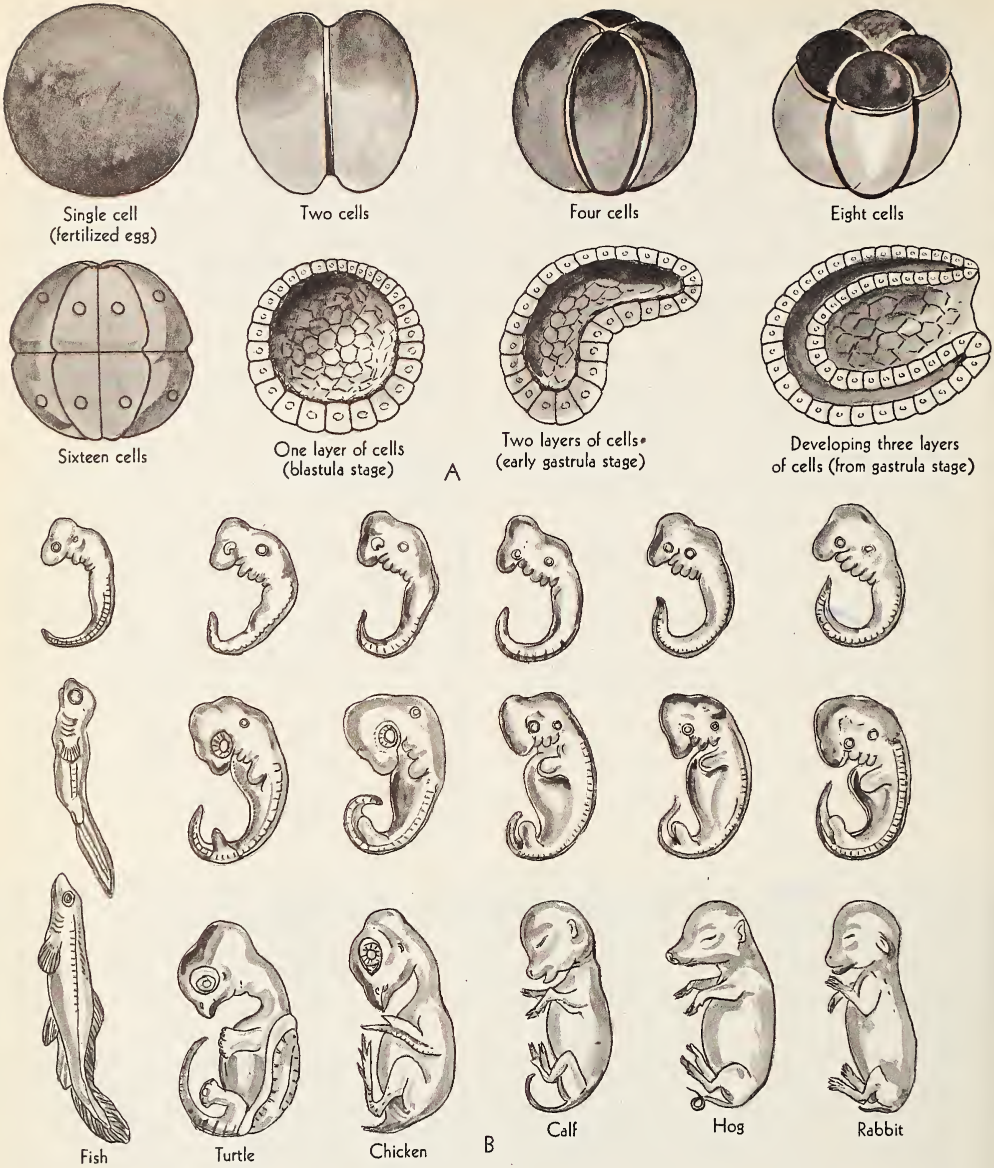
5. Producing new fruit trees by grafting is an example of controlled __?__ reproduction.

6. Some of the *higher* animals can develop into complete animals from a part of an adult of the same kind.

Pages 434–442. **7.** In conjugation two cells unite to form *two* new *organisms*.

8. One way in which an asexual spore differs

[1]*Blastula* (blăs'tū lȧ). [2]*Gastrula* (găs'trōō lȧ). [3]Page 151.



A, early stages in the development of a vertebrate embryo; *B*, three later stages of several vertebrate embryos. How would you explain this illustration to somebody of your own age who has not studied biology?

from a sexual spore is that the *asexual* spore results from the union of two cells.

9. In fertilization usually a large, stationary *sperm* is united with a *small*, swimming *egg*.

10. An example of an animal that has both male and female sex organs is (1) *Paramecium*; (2) *Ulothrix*; (3) earthworm; (4) fish; (5) toad.

11. Mitosis results in the forming of *sex* cells, and hence is the process that results in an organism's growth.

12. Reduction division results in the formation of __?__ or eggs, and hence makes reproduction possible in higher animals.

13. As a result of mitosis, each daughter cell has (1) double the usual number of chromosomes; (2) half the usual number of chromosomes; (3) the usual number of chromosomes; (4) no chromosomes at all; (5) an indefinite number of chromosomes.

14. As a result of reduction division, each gamete has (1) double the usual number of chromosomes; (2) half the usual number of chromosomes; (3) the usual number of chromosomes; (4) no chromosomes at all; (5) an indefinite number of chromosomes.

15. A fertilized egg has (1) double the usual number of chromosomes; (2) half the usual number of chromosomes; (3) the usual number of chromosomes for that species; (4) no chromosomes at all; (5) an indefinite number of chromosomes.

16. When an egg cell is fertilized by a sperm bearing an X chromosome, the offspring will be a *male*.

Pages 442–448. 17. In alternation of generations the offspring in each generation resembles its *mother or father*.

18. In alternation of generations a *sexual* phase alternates with an *asexual* phase.

19. The sex organs of a flowering plant are all located in its (1) flowers; (2) leaves; (3) roots; (4) stems; (5) fibrovascular bundles.

Pages 448–454. 20. Self-fertilization occurs only in lower *vertebrates*, and self-pollination takes place only in some of the *highest* plants.

21. Cross-fertilization takes place in *some* invertebrates and *all* vertebrates, and cross-pollination occurs in *all* plants.

Pages 454–459. 22. State at least five ways in which plants are spread to new localities.

23. The lower a plant or an animal is in the scale of life, the *greater* are the chances that every egg will be fertilized and every individual will grow to maturity.

24. State the principal stages of development of a mammal from the fertilization of the egg to the point at which organs begin to develop.

25. *Most* communicable diseases can be inherited.

BIOLOGICAL PRINCIPLES · 1. Every cell develops from another cell.

2. Every embryo begins life as a fertilized egg.

3. Every living thing is descended from either one or two parents.

4. Simple organisms may reproduce asexually by fission, by forming spores, or by vegetative reproduction.

5. Some living things reproduce by the union of two similar cells, whereas others reproduce by the union of two unlike cells.

6. Living things die, but life continues from age to age.

7. Some living things reproduce asexually in one generation, and sexually in the next.

8. In general, living things produce many more young than can possibly survive.

9. Many organisms would soon become extinct if they did not produce enormous numbers of young.

BIOLOGICAL TERMS

**calyx	**egg	**stamen
**chromosome	**ovary	**pollen
**corolla	**pistil	**testes
**fertilization	**sperm	

Applying and Extending What You Know

AS SCIENTISTS WORK AND THINK · **1.** Which of the elements of scientific method are indicated in the experimenting by Woodruff on *Paramecium*?

2. Not many years ago many persons believed that decaying meat turns into maggots by spontaneous generation. Using the elements of scientific method, plan and carry out an experiment to obtain evidence on this problem. Make certain to introduce proper controls and to include check experiments.

CONSUMER EDUCATION · **1.** List some important facts that a buyer of fruit trees needs to know about grafting.

2. Some persons who are allergic to certain pollens cannot eat honey. Can you explain this statement?

3. Sometimes the eggs that we buy have red spots on the yolks. What causes these spots? Do they make the eggs unwholesome?

4. Can you think of a reason why the sale of oysters or other shell-fish is commonly forbidden by law in the months that have no *r's* in their names?

APPLYING YOUR KNOWLEDGE OF BIOLOGY · **1.** Farmers cut large potatoes into pieces for planting. Why do they do this? Why must each piece have at least one "eye"?

2. From your own experience, make lists of plants that are propagated from seeds, cuttings, roots, and bulbs.

3. Under certain conditions bacteria will reproduce by fission once each hour. Assume that they all live. How many descendants will one bacterium have in twenty-four hours? Of what importance is this fact? Most of them do not live. Why do they not? To which of the biological principles on page 461 does this exercise most closely relate?

4. How many organisms discussed in this chapter have two or more methods of reproduction? Justify your answer.

5. What parts of the development of a mammal correspond with parts of the development of ferns and mosses?

TOPICS FOR INDIVIDUAL STUDY · **1.** In a garden encyclopedia find out how various kinds of grafts of fruit trees, roses, grapes, and other kinds of plants are made. Make a report in your class or in your science club. Also, make and label sketches for a bulletin-board display.

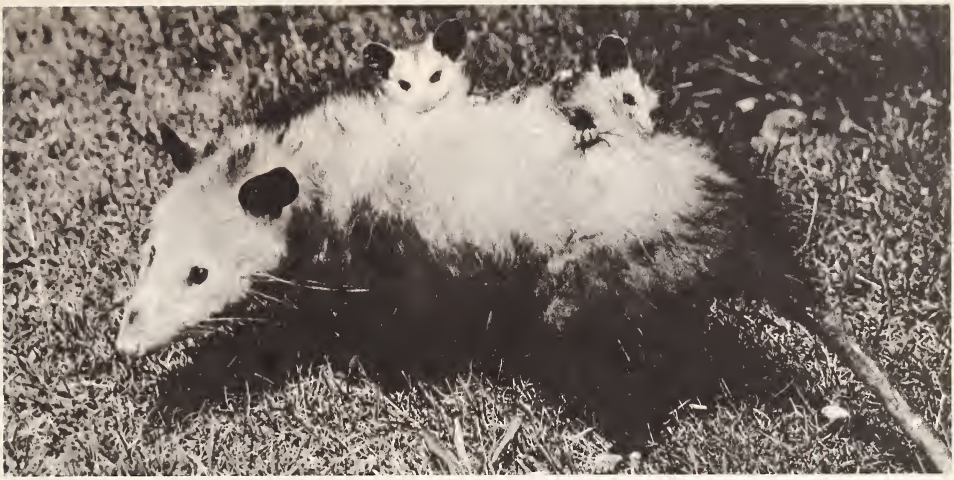
2. Consult an advanced textbook of zoology to learn about the method of reproduction of fresh-water sponges by gemmules.[1] Which of the methods of reproduction described in this chapter does reproduction by gemmules most closely resemble?

3. In an advanced botany textbook find how the aerial roots of a banyan tree are formed. Is this an asexual or a sexual method of reproduction?

EXPERIMENTS · **1.** Which of a number of kinds of plants can be propagated from cuttings? Obtain cuttings from a number of different kinds of trees and other plants. The cuttings should be obtained early in the spring before the buds swell. Place these cuttings in water. Change the water three or four times weekly. Observe the cuttings for at least a month. Which plant cuttings develop roots? Which do not?

2. Can parts of earthworms regenerate complete individuals? Obtain four earthworms of as nearly equal length as possible. Fill seven cans or flower-pots about two-thirds full of humus or top-soil. With a new razor blade cut one earthworm into two parts by dividing it at a point about one fourth of the distance from the anterior to the posterior end. Put the short, anterior end into one of the cans or pots of soil, and the longer end into another. Label these containers, respectively, "Earthworm *A*, anterior quarter" and "Earthworm *A*, posterior three quarters."

[1] *Gemmule* (jĕm'ūl).



Wide World

The young of the opossum, like those of the kangaroo, live for a while after birth in the mother's pouch. How is such an adaptation as this an aid to survival?

Divide a second worm into halves, put the two halves into two separate containers, and mark these, respectively, "Earthworm *B*, anterior half" and "Earthworm *B*, posterior half." Cut the third earthworm into two parts, by dividing it at a point about one fourth of the distance from the posterior to the anterior end. Place the two parts in different cans or pots marked, respectively, "Earthworm *C*, anterior three quarters" and "Earthworm *C*, posterior quarter." Do not divide the fourth earthworm, but place it in the remaining can. Label it "Earthworm *D*, entire." Why is it important to include this whole worm in the experiment? Be sure that all the parts are well covered with the soil. Set all the containers aside for three days, then examine the worms in all the containers. Which portions of the earthworms are still alive? Continue to examine the living portions of the worms for several weeks at intervals of about three days. Keep careful notes of your observations. What conclusions can you draw from this experiment?

WHY NOT BECOME A NATURALIST? · 1. What can you learn about plant reproduction? Take a "nature hike" or several of them through the woods, a park, or fields. Look for dry puff-balls. If you find one, open it and note the cloud of greenish-brown spores which comes out of it. Look for the spore-producing organs (sporangia) on the lower surfaces of fern leaves. Find the tall stalks on moss plants with capsules on their ends, within which spores develop. Study leafy moss plants to see if you can find the sperm cases (antheridia) and the egg cases (archegonia). Study various kinds of flowers to learn which are complete and which incomplete, which is a male (staminate) flower and which a female (pistillate) flower. Keep careful notes of your observations.

2. Can you find amphibians' eggs and evidences of care of the young? Take a "nature hike" or several of them through the fields, woods, or a park. If you are "hiking" in the spring of the year, look for clusters of frog eggs or strings of toad eggs in ponds. These may be brought, along with some pond-weeds, into the classroom to be kept in a jar or aquarium so that their development may be watched. In streams and along the shores of lakes, look for places

International

Quintuplet kids are probably as rare as quintuplet human babies. These young goats are being fed partly from nursing bottles because the mother cannot supply enough milk for all. If these were wild goats, all but one or possibly two of the kids would starve to death. What factors do you think would determine which would survive?

where male sunfish are guarding the nests in which eggs have been laid by the females. Look for different kinds of birds' nests, noting how they have been made; where they are located; and, if possible, what kinds of birds made them.

Springtime is a good time to look for rabbits' nests. If you find such a nest that has been deserted, note how it is hidden away and how it is lined with soft fur from the female's body. Keep careful notes of your observations.

3. What can you learn about flower parts? Examine as many different flowers as you can and note differences in color, odor, and parts present. Note also the differences in numbers of petals, stamens, pistils, etc. Note, too, the structures which make possible or which prevent self-pollination or cross-pollination, etc. Add sketches to your notes of your observations.

Your nature notes will provide excellent material for English themes and articles for your school paper.

4. Find a nest of young birds. Observe whether one or both parent birds feed the young. Note how often the young birds are fed and with what kinds of food. Note their development. Record all your observations.

5. Whenever you are where wild flowering plants or trees are in bloom, try to find examples of flowers which are not likely to be noticed. Keep careful notes and make sketches of what you observe.

COMMUNITY APPLICATIONS OF BIOLOGY · **1. Studying a commercial chick hatchery.** If there is a chick hatchery near your home or school, make arrangements to visit it. Find out the temperature at which the eggs are maintained, how long they are incubated, how they are tested to determine whether the embryos in them are developing, how the humidity in the incubators is regulated, why the eggs must be turned daily, and how the young are cared for upon hatching. Take careful notes as a basis for later reports.

2. Studying a fish or shell-fish hatchery. Visit a fish hatchery, lobster hatchery, or oyster hatchery if there is one in your vicinity. Find out what methods are used to propagate these animals. Take careful notes as a basis for later reports.

BULLETIN-BOARD DISPLAY · Select flowers from plants which you have found growing in your neighborhood or which you have grown as house plants. Make drawings, either in black and white or in color, showing enlarged views of a complete flower, a male (staminate) flower, a female (pistillate) flower, and a flower without a corolla. Label each drawing with the name of the plant represented and label also the various structures. Display on the bulletin board the results of your work.

17

LIFE—PAST, PRESENT, AND FUTURE

1. How Do Living Things Change from Age to Age?

If you could have visited the part of North America that is now Kansas, a hundred million years ago, you would have found it covered by a warm ocean. You might have seen great reptiles swimming about in the water or flying over it (illustration, p. 466).

During the same period, what is now Wyoming was swampy country. In one of the swamps you might have seen a great "Thunder Lizard" nearly seventy feet long, being attacked and killed by another dinosaur[1] (*Tyrannosaurus*[2]), at least eighteen feet high. The larger animal would be offering no effective resistance. The "Thunder Lizard" was herbivorous and had neither teeth nor claws of a sort with which it could defend itself. It was too big, however, and too well protected by its thick "armor," to be harmed by many things besides the great carnivorous reptiles.

Besides such monsters of ocean, air, and land, you might have seen other strange and terrifying early inhabitants of "Kansas" and "Wyoming." There were, however, in the same habitats many small reptiles no bigger than present-day lizards, as well as other animals no more remarkable than those of today.

RECORDS OF PAST LIFE · Scientists have no doubts that the warm ocean, the swamps, and the great reptiles existed in those localities at somewhere near the time indicated. They are able to piece together much of the history of any region from a study of the rocks and the bones which have been found there (illustration, pp. 468–469).

Not only the Age of Reptiles, but also other periods as well, had their strange animal and plant forms. If you could have visited the site of Los Angeles fifty thousand to one hundred thousand years ago, you would have had a chance to see animals which you would have called lions and elephants. You could also have seen others, which you would have called camels, even though some of them were fifteen feet high and others the size of cats. You might have encountered still others, such as saber-toothed tigers and mastodons, which would have been entirely strange to you.

It has been easier for scientists to find out what animals lived in the locality where Los Angeles now is than what kinds lived in other places, because of the "tar pits" there. These were deep deposits of asphalt. Animals that came to drink the water that had collected on top got stuck in this asphalt and began at once to sink out of sight. Predators discovered that they were unable to get away and hence approached to attack them. Then these predators likewise became caught in the asphalt and slowly disappeared into it.

As a result, there are preserved in these asphalt deposits the bones of most of the dif-

[1]*Dinosaur* (dī'nō sôr).
[2]*Tyrannosaurus* (tĭ răn ō sô'rŭs).

Buffalo Museum of Science

Former inhabitants of the Middle West · Nobody yet knows why these great reptiles became extinct. Perhaps the climate changed faster than they could become adapted to it. Perhaps diseases exterminated them. How many other possible reasons can you suggest?

ferent kinds of animals that have lived in what is now southern California from thousands of years ago until now (illustration, p. 470). Within recent years hundreds of complete skeletons secured from the tar pits have been put together and classified.

KINDS OF FOSSILS · The bones of dinosaurs and of the animals in the tar pits are fossils. A fossil is any kind of naturally preserved evidence of ancient animal or plant life. Fossils are of several kinds besides bones. The ones most commonly found are the shells of water animals, such as mollusks[1] and corals.[2] Ages ago these shells became buried in the mud, sand, or fine gravel that settled to the bottoms of oceans, lakes, and rivers. In time these deposits hardened to rock.

Some fossils are the tracks or other prints made by animals and the prints of plants in mud that later became changed to rock. Many rocks have been found in New England that have in their surfaces the huge, bird-like footprints of dinosaurs. Sometimes this type of fossil is a worm cast (excreta) turned to stone. Often it is the print of a fern or other plant on a piece of coal.

Petrified structures of plants and animals also are common fossils. The Petrified Forest of Arizona is famous for its acres of petrified trees. Such fossils are not living things that have been turned to stone, as they appear to be, and as many people believe them to be. They were formed in moist soil containing certain dissolved minerals. As the organic matter of the living things decayed, its place was taken by the inorganic matter, namely, the minerals deposited from the water.

A rare kind of fossil is a fly or other insect buried in amber. Amber is a hardened pitch, or resin, that came from pine trees ages ago.

[1]Page 524. [2]Page 517.

Still another kind is an organism that has been preserved by "cold storage." Less than fifty years ago an important fossil of this kind was found in Siberia. It was the body of a mammoth, almost whole (illustration, p. 472). This one had been standing at the bottom of a steep hill, eating plants, when a land-slide buried it. Before the body could decay, the ground froze and remained frozen during many centuries.

Some years ago the body became uncovered. Wolves found it and ate part of the animal's trunk. Before the rest could decay or be eaten by wolves, it was discovered by a party of hunters. It was later removed by Russian scientists to a museum. Since then, a number of other mammoths have been found preserved in frozen Siberian swamps.

ACCOUNTING FOR THE FOSSILS · When fossils first began to attract attention, everybody was puzzled by them. Even the greatest scientists could not agree upon what they were or how they happened to be where they were found. Many of the bones, and shells found in rock, closely resembled similar structures of animals then living. Others were unlike those of any known living things.

The problem of accounting for them was made more difficult by the fact that fossils similar to the shells of present-day sea animals were often found on the tops of mountains. People did not then know that many present mountain-tops were once ocean bottoms. Also, bones of animals that scientists were sure had belonged to elephant-like and horse-like animals were found where, so far as anybody then knew, no such creatures had ever existed.

LIVING THINGS CHANGE · [E]The evidence supplied by fossils convinced scientists that [P]the kinds of plants and animals that inhabit the earth change in form and structure over

Recent twenty to thirty thousand years

ORGANISMS IMPORTANT
DURING THE PERIODS

Age of Man

CENOZOIC

Late

Mammals abundant
Many kinds now extinct

Middle

Age of Herbaceous Plants

Many plants and animals
resembling modern forms

Early
Primitive forms of modern
mammals
Early monocots

MESOZOIC

Late
Dinosaurs become extinct
Early flowering plants
Age of Reptiles

Middle
First trees like
present-day kinds
First birds

By studying rock formations, geologists have learned which are the oldest layers and which the most recent ones. By studying the fossils found in the rocks, scientists have been able to piece together a partly complete history of living things. The older the geological period, the simpler in structure and the less like modern forms are the remains of the plants and animals found in its strata. Also, the older the period, the less certain is its estimated time. How much of this "Time Chart" do you think is prehistoric? Explain

An artist's idea of a scene at the California tar pits many thousands of years ago · Merriam,[1] an American scientist, made the first extensive collection of complete skeletons from the asphalt. Scientists have "reconstructed" from these skeletons models which they are sure are correct in size and form in all essential features. Can you suggest important questions that might be answered from a study of such a collection as the one Merriam made? **Correlating Biology with English:** Write a theme for your English class, based upon this picture. (The animals are a ground sloth, a saber-toothed tiger, dire wolves, and condor-vultures)

[1]Born, 1869.

long periods of time. It convinced them, also, that [P]some kinds of organisms become extinct and that new species appear. The evidence, especially that obtained from the tar pits, indicated further that [P]slight changes in plants and animals occur from generation to generation.

A number of theories were invented to explain how some plants and animals could be so different from earlier forms to which they seemed to be related. Many scientists believed it impossible that such great differences between ancient and modern forms of life as the fossils showed could have resulted from even long series of small variations. They looked for further evidence which would throw light on the ways in which living things change.

MUTATIONS · [E]Scientists had noted that the changes in plants and animals from one generation to the next are not always slight. Sometimes they are marked. For example, in a bed of flowering plants with single blossoms, one may appear that has double blossoms. In a litter of pigs one is occasionally found that has solid hoofs, like those of a mule or a horse, instead of split hoofs, such as pigs normally have. Furthermore, the offspring of the double-blossomed plant may have double blossoms. Those of a mule-footed pig are almost certain to be mule-footed.

Such abnormal individuals are fairly common and are known as sports or mutants.[1] The variation itself is called a mutation.[2] Some scientists state, however, that a mutation need not be marked. It may be slight, though it is often conspicuous.

DE VRIES'S STUDY OF MUTATIONS · It occurred to De Vries,[3] a noted Dutch botanist, that mutations might explain the great differences between present-day and ancient organisms. To get mutations for study, De Vries raised evening primroses in great numbers. Mutations appeared now and then among these plants. For example, an occasional young plant would have different foliage or different flower color from the usual one. Such a plant, moreover, in most cases bred true; that is, most of the plants propagated from it had the new character.[4]

De Vries continued his study of mutations for nearly ten years. During that time he raised at least fifty thousand evening-primrose plants. Finally, in about the year 1900, he announced his theory of mutations. According to this theory, plants and animals change, not slowly, over long periods of time, but at once. Thus new species are produced in a single generation.

This theory was accepted by scientists as a valuable addition to earlier ones that attempted to account for changes in plant and animal forms through long series of slight changes.

OTHER EXPERIMENTS WITH MUTANTS · Many scientific studies of mutations have been made since De Vries announced his theory. The American zoologist Morgan[5] worked with fruit flies. At least a thousand mutants have been found and studied among the hundreds of thousands of fruit flies raised by all the scientists who have studied them.

NOT ALL VARIATIONS TRANSMITTED · It must not be concluded from the preceding paragraphs that all the variations that plants and animals show are transmitted from their parents to their offspring. The results of

[1]*Mutant* (mū'tănt). [2]*Mutation* (mū tā'shŭn).
[3]*De Vries* (dĕ vrēs'); lived, 1848–1935.

[4]Any characteristic, or trait, such as height, color, size, shape of leaf or of ear, or length of nose, is a *character*.

[5]Lived, 1866–1945.

© Chicago Natural History Museum

There is a picture of a mammoth which was painted on the walls of a cave in France by a member of a race of people (Cro-Magnon[1]) now long extinct. The fact that one of them could paint a mammoth indicates that mammoths and these primitive men were contemporaries (living at the same time). Which of the elements of scientific method (p. 570) is illustrated by the preceding statement?

many experiments show that slight variations are not necessarily inherited, as some scientists had assumed that they always were.

Scientists, and others as well, have discovered, too, that not all plants and animals that vary greatly from their parents pass on their peculiar characters to their progeny. Many of them never grow to maturity and hence produce no offspring. Some that do, have offspring, not like themselves, but like normal individuals. For example, there have been side-show "freaks" with unusual structures, whose offspring were normal, like their grandparents. In most cases, however, an abnormal individual that is a true mutant does transmit its new character to its offspring.

The terms *freak* and *mutant* are used with the same meaning by some authors. By others *freak* is used to mean an abnormal individual that does not pass on its unusual variation (illustration, p. 474). An example of an animal that would be called by such writers a freak, but not a mutant, is given by the great American zoologist Ditmars,[2] in his *Reptile Book*. This animal was a two-headed milk snake. The two heads would have "energetic quarrels" over the young mice that served as the animal's food, even though both throats joined in a body that had only one stomach. The heads usually tried to go in different directions, with the result that the animal's progress was slow and not like that of normal snakes. The two heads were as independent as if they belonged to different bodies. Often one head was active

[1]*Cro-Magnon* (krō mȧ nyôn′).

[2]Lived, 1876–1942.

while the other was quiet. This snake lived for about a year and became about two-thirds full-grown.[1]

SUMMARIZING AND INTERPRETING THE CHANGES IN PLANT AND ANIMAL FORMS · No entirely satisfactory theory to explain how plants and animal forms change has yet been suggested. Moreover, what the exact nature is of the "sorting process" that allows certain kinds of animals and plants to live in a locality and causes others to die there is not yet certainly known. Scientists are, however, in general agreement on the following principles of heredity**[2]:

1. ᴾIndividuals vary from generation to generation by inheritance.[3] ᴾOffspring are never exactly like their parents, and no two offspring are ever exactly alike. They always differ more or less with respect to their various characters. These differences between one generation and the next may be slight, as in the case of most variations, or they may be marked, as is shown on this page.

2. ᴾAlways too many organisms are produced for the habitat to support. Most of them must die early. Relatively few can long survive. Hence there is a constant "struggle for existence." This is a never ending struggle, in which every plant and animal strives to get as much as it needs of all its life necessities. The struggle for existence results in "natural selection" of the individual plants and animals that can survive. Natural selection is a sorting process by which those that are able to withstand all the conditions in the habitat live and those that cannot, die. Thus natural selection brings about a "survival of the fittest."

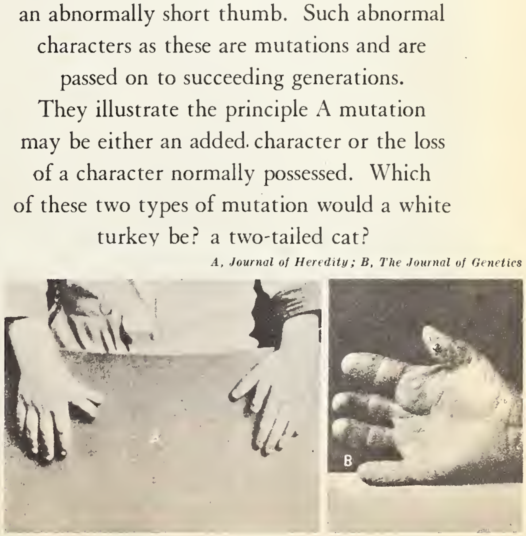
By "fittest" is meant "best suited to the conditions of the habitat." Hence the "fittest," which succeed in remaining alive, are not necessarily the largest or the strongest. For example, an evergreen tree that has the character of deep-growing roots is more likely to survive an unusually severe wind-storm than another that has shallow-growing roots. In a cold climate a small and relatively weak and timid wolf with abnormally thick fur may survive an unusually cold winter, while its larger, stronger, and fiercer litter-mates may freeze to death.

3. ᴾAs a result of natural selection, which is constantly bringing about a survival of the fittest, the structures of plants and animals are modified (changed) to a smaller or a greater extent from generation to generation. The plants and animals that have the variations in characters that make their survival easier are the ones most likely to live long enough to reach maturity and to have offspring.

4. ᴾThe progeny of successful organisms which inherit the favorable characters of their

A, each of these hands has two thumbs; **B**, this hand has abnormally short fingers and an abnormally short thumb. Such abnormal characters as these are mutations and are passed on to succeeding generations. They illustrate the principle A mutation may be either an added character or the loss of a character normally possessed. Which of these two types of mutation would a white turkey be? a two-tailed cat?

A, Journal of Heredity; B, The Journal of Genetics



[1]Page 507, No. 3.

[2]*Heredity* (hē rĕd'ĭ tĭ): the transmission, or "passing on," of characters from parent to offspring.

[3]*Inheritance* (ĭn hĕr'ĭ tăns): the reception of characters from ancestors.

parents are the ones most likely to survive. Hence the proportion of offspring that have a favorable character is likely to become greater in each succeeding generation. After a long enough time all the plants or animals of the same kind may have the favorable character. For example, all the evergreens may have deep-growing roots, or all the wolves thick fur. Thus, as far as any particular character is concerned, the members of the present generation may be greatly different from their remote (distant) ancestors.

5. [P]Conditions in every habitat are constantly changing. For example: New animals and plants may join the community of living things.[1] The climate may become moister or drier, colder or warmer. Fire or flood may pass over the locality. Consequently the character that was most favorable to the survival of a plant or an animal a generation or so ago may no longer be so. Hence [P]all the kinds of living things must constantly keep changing as their habitats change. If any kind

[1] Page 24.

This sheep is normal except that it has a fifth small, well-formed but undeveloped leg. Do you think that the animal is likely to be a freak or a mutant? How would it be possible to find out? Such freaks as Ditmar's two-headed snake and Cuthbert the Great (illustration, p. 5) are really each a pair of imperfectly divided twins

Wide World

fails to change enough so that it can survive under the new conditions in its locality, it becomes extinct there.

THE SORTING PROCESS AND MAN · [E]The sorting process, natural selection, described in the preceding paragraphs is constantly going on among people, though not so extensively and noticeably as among the plants and the lower animals. To illustrate: In certain Asiatic countries where the populations are dense, where enough food is not available, and where sanitation is poor, the weaker, more completely exhausted, and under-nourished people are constantly dying in greater numbers than those who are more "fit." Parts of Colorado, New Mexico, and Arizona were once populated by a highly advanced people (illustration, p. 167). One or more of the sorting factors—famine, change of climate, disease, war, etc.—might have been the cause of their becoming fewer and fewer, and finally disappearing entirely. Nobody knows.

Civilization, by its efforts to care for the less fortunate individuals, reduces the effects of this sorting process among human beings. Nevertheless among human beings the struggle for survival takes place on mental, social, and economic levels, as well as on the physical level, as the following examples indicate: There is always keen competition for desirable jobs. Those best qualified, among the ones who apply, are most likely to get the jobs and to hold them. The considerable amount of evidence available clearly indicates that, in general, those who are the "best students" in school are the ones most likely to be successful in after-life. The day-dreamers and the wishful thinkers are not so likely to be popular or successful as those who use their energy wisely. Doubtless you can think of many other examples.

2. What Are Some Further Important Discoveries concerning Heredity?

According to a credited account, one of the greatest biological discoveries of all time resulted indirectly from a dispute. In 1856 Mendel,[1] a monk in the Augustinian monastery at Brünn, Austria-Hungary,[2] was taking examinations to qualify as a regular teacher in the technical high school conducted by the monastery. During the examination Mendel got into an argument with one of the examiners about some aspect of plant propagation. The argument became so heated that Mendel left the room without completing the examination. Consequently he did not qualify as a regular teacher, although some years later he became the abbot of the monastery.

A "MILESTONE" OF BIOLOGY · Mendel was not content to drop the matter about which he had been arguing. He determined to carry on investigations to find out whether or not his ideas on the subject were correct. The research (investigation) which he did during the next eight years laid the foundations for the modern science of heredity. The principles that he discovered have proved of

[1]Lived, 1822–1884.

[2]The territory in which Brünn is located became a part of Czechoslovakia after the First World War.

enormous practical value in modern plant and animal breeding.

THE PROBLEM OF THE INVESTIGATION · Mendel's problem was to find out in what ways offspring may be expected to resemble their parents. Earlier investigators had tried to compare one generation of plants or animals with the next in as many respects as they could observe parents and offspring to be alike or different. Their findings had proved of little value. Mendel decided, instead, to study the inheritance of single traits, or characters, such as color or height, one at a time, without regard to others that might be present.

THE PRELIMINARY STEPS · He began his research with mice, but soon found them too difficult to take care of with the available facilities. After careful consideration he decided to experiment with peas. He was given the use of a small plot of ground beside the monastery for growing his plants (illustration, p. 478).

Mendel wanted to start with pure varieties, or strains. A pure, or purebred, variety is one that breeds true and thus has the same characters generation after generation. Peas are nearly always self-pollinating. Hence any peas that Mendel might use would probably be pure strains. But he had to make sure that they were.

To do this he planted the seeds of thirty-four varieties. The second season he planted the seeds that he obtained from the first season's crop. From the crop that grew from this second season's planting, he selected fourteen varieties each of which (1) had bred true

These lizards have been found nowhere except on the Galapagos Islands, where they are known to have lived for centuries. These volcanic islands are in the Pacific Ocean, nearly six hundred miles west of the coast of Ecuador. Which of the five principles on pages 473 and 474 do you think is best illustrated by the Galapagos lizards?

American Museum of Natural History

Killian, from United States Department of Agriculture

"Bagged" peach blossoms · Sometimes blossoms that are self-pollinating are bagged. Can you think of a reason for doing this?

in both seasons and hence was almost certainly a pure strain, and (2) had one distinct character that contrasted with a corresponding character in another.

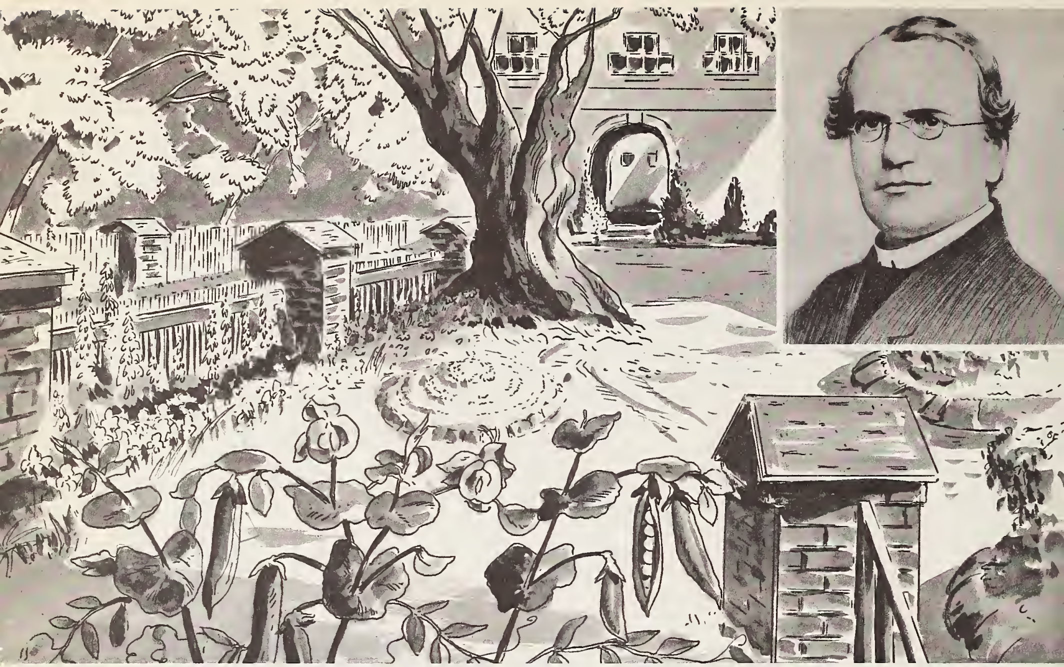
Thus he had seven groups of plants with two contrasting characters in each group. These contrasting pairs of characters included white flowers and purple flowers, green seeds and yellow seeds, short stems and tall stems, and so on.

THE EXPERIMENTS · In the third year Mendel planted, in separate plots, the seeds of the fourteen pure strains that he had raised. He cross-pollinated[1] the blossoms of plants that had contrasting characters. In doing this he used the following method of hybridization,*[2] which is the same as that used by plant-breeders today:

Just before a bud was ready to bloom, he opened it and cut off its stamens. Then, on each pistil, he put pollen from the stamens of a flower that was in bloom on a plant having the contrasting character. In this way he cross-pollinated white and purple flowers, flowers with yellow seeds and those with green seeds, flowers of short plants and those of tall plants, and so on. He alternated the plants that supplied and received the pollen. Thus he pollinated a white flower with pollen from

[1]Page 449.

[2]*Hybridization* (hī brĭd ī zā'shŭn): the process or method of producing *hybrids* (hī'brĭdz). *Hybrid:* a plant or an animal produced by parents of two different varieties or species, or the offspring of parents that differ in one or more characters.



The garden where Mendel did his experimenting · How many of the elements of scientific method can you identify in the story of Mendel's work told in the text?

a purple one, then a purple flower with pollen from a white one.

As soon as he had pollinated a blossom, he covered it with cloth or paper to prevent bees or other agents from carrying any more pollen to the pistils (illustration, p. 477). He then marked each flower to indicate the variety of plant with which it had been crossed. Thus he had seven groups of pollinated flowers in each of which two contrasting characters had been combined into a pair.

THE RESULTS · The following summer he planted the seeds obtained from these plants. What would be your guess with respect to the characters of the plants that he obtained in the first (F_1[1]) generation? Should you expect that all variations of the two contrasting characters within each group would appear? For example, should you expect all shades of flower color from white to purple? all shades of seed color between yellow and green? or all heights from short to tall? Or should you expect that all the plants would have characters "halfway between" those of the parent plants, that is, whitish-purple flowers, greenish-yellow seeds, or medium height? Or that the entire crop would show the same fourteen characters that the parent plants had possessed?

Mendel had none of these results. Instead, he found that only seven of the original fourteen characters appeared, that is, only one of each two contrasting characters that had been combined. Thus all the plants of one group had purple flowers. All those of another group had yellow seeds. All of a third were

[1]The symbol F_1 means the first filial, or daughter, generation, that is, the first generation of offspring. (If the parents were counted as the first generation, the F_1 generation would be the second generation.)

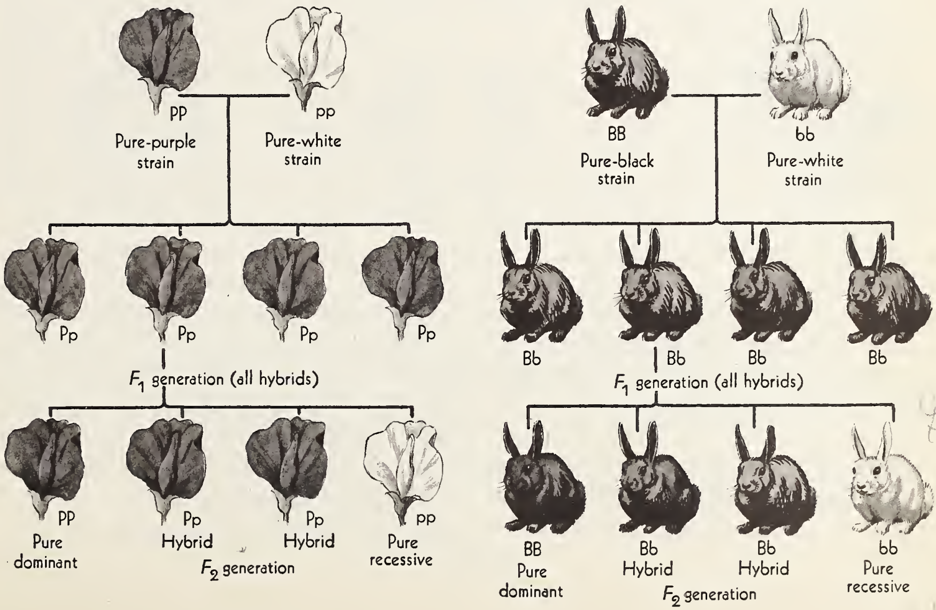
tall. There were no plants in the first group that had white flowers (illustration below), none in the second that had green seeds, and none in the third that had short stems.

DOMINANT AND RECESSIVE CHARACTERS · Mendel decided to give the name *dominant**[1] *character* to a character which one parent plant had had, and which all the plants of the F_1 generation had that had been propagated from it. Thus purple flower-color, yellow seed-color, and tallness of the plant were dominant characters. He decided to give the name *recessive**[2] *character* to a character which one parent plant had had, but which none of the plants of the F_1 generation had that had been propagated from it. Thus white flower-color, green seed-color, and shortness were recessive characters. Hence purple was dominant over white in the flowers, yellow over green in the seeds, and tallness over shortness in the plants.

[1]*Dominant* (dŏm′ĭ nănt). [2]*Recessive* (rē sĕs′ĭv).

THE NEXT STEPS AND RESULTS · Mendel let these hybrid F_1 plants reproduce by self-pollination. Then the next season he planted their seeds. Again, what would be your guess about his results? That all fourteen characters appeared in this F_2 generation? That

How Mendel's experiments with purple-flowered and white-flowered plants resulted in the F_1 and F_2 generations, and how a similar experiment with rabbits would result. Purple (**P**) and black (**B**) are both dominant over white. Which individuals of the F_2 generation are like their grandparents? Which are like their parents? Where are the 1 : 2 : 1 ratios in these drawings?



only the seven dominant characters appeared? That fewer than seven characters appeared? Or that none of the original fourteen characters appeared, but that many new characters did?

The first is the correct answer. Mendel found both the dominant and the recessive characters present in this second, or F_2, generation. They were not, however, in equal numbers. About three fourths of the plants showed the dominant character, and one fourth the recessive. Thus there were three with purple flowers for every one with white (illustration, p. 479), three with yellow seeds for every one with green seeds, three tall plants for every short plant, and so on.

By later experiments he found, in each F_2 generation such as this, (1) that one of every three plants that appeared to be alike was a pure dominant, and (2) that the other two were hybrids with the dominant character. In other words, each F_2 generation was composed of plants in the ratio of one pure dominant, two hybrids with the dominant character, and one pure recessive. This ratio is known as the 1:2:1 ratio.

Mendel carried on his experiments during four more seasons. He repeated those that he had already done and made others with new crosses, such as hybrids with pure or purebred strains, and pure dominant (F_2) with pure recessive (F_2) strains. At the end of his eighth season of experimenting he was able, from his careful research and complete records, to state several biological principles of great importance. Biologists later proved that these principles operate in both plant-breeding and animal-breeding.[1]

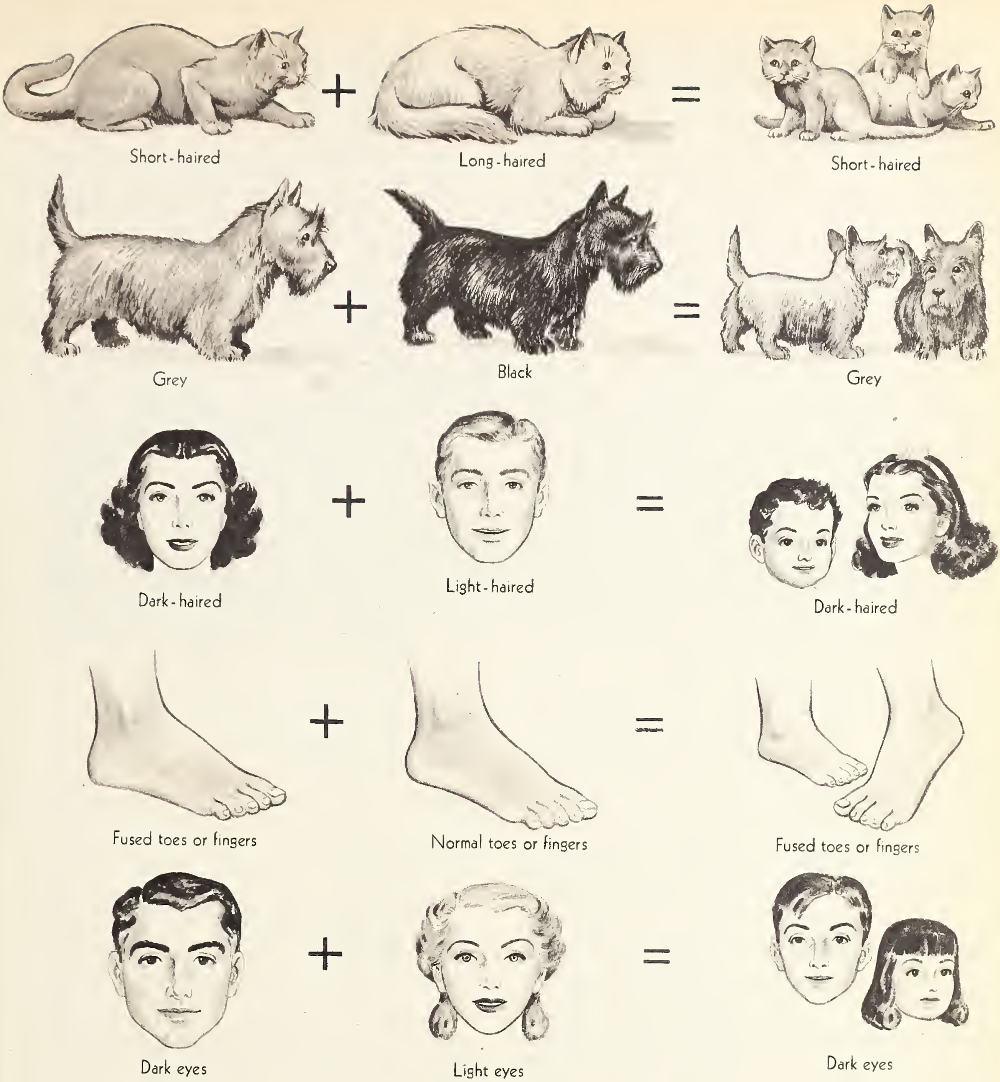
MENDELIAN PRINCIPLES · Below are three of the simpler principles which Mendel discovered and announced. They hold true, however, only when great numbers of individuals are involved—perhaps a thousand, at least, in each case.

1. Dominance. ᴾHybrids produced by crossing parents with contrasting characters will have one of these characters, and it will be the dominant one (illustration, p. 479). Thus, when Mendel crossed a pure strain of tall pea plants with a pure strain of short plants, all in the resulting (F_1) generation were tall. Curliness of human hair is dominant over straightness. Hence the children of a straight-haired parent and a curly-haired parent, if each parent is from a pure strain with respect to the trait, will all have curly hair. In these two examples the recessive traits, shortness of plant stem and straightness of hair, do not appear at all in the F_1 generation (illustration, p. 479).

2. Segregation, or separation. ᴾCharacters continue to appear as separate units in succeeding generations. They are not united or blended, nor are they lost. Recessive characters are masked, or submerged, provided that the dominant characters are present. But they may be expected to appear again in later generations. Thus, in the F_1 generation of pure strains of white-flowered and purple-flowered plants, Mendel found only purple-flowered plants. In the next generation, however, he found that the color characters had again separated, with the result that some plants had purple flowers and others white ones. But none had purplish-white flowers. Children of a red-haired and a dark-haired parent are likely to have dark hair. In any case they will not have part of their hair dark and the rest red. Furthermore, although dark hair color is dominant over red, some of these parents' descendants will have red hair.[2]

[1] Page 507, No. 3.

[2] As Scientists Work and Think, No. 3, p. 570.



In each case represented here, the first trait of each pair of contrasting traits is dominant, and the second recessive · From their studies of contrasting human characters, scientists have discovered the following facts: Kinky hair is dominant over curly hair; curly hair, over wavy; and wavy, over straight hair. Normal hearing is dominant and deaf-mutism recessive. Normal sight is dominant and night blindness recessive. Normal skin and hair coloring are dominant and albinism (illustration, p. 488) recessive. **Topic for Individual Study:** Dominance and recessiveness with respect to other pairs of human traits

3. Independent assortment. ᴾThe characters of an organism are inherited independently. Thus Mendel found that the inheritance of color was separate from that of tallness in pea plants. He found that a tall pea plant might have either white flowers or colored ones, and so also might a short plant. Among people, a slightly built person may have blue, green, or brown eyes, and so also may a heavy-set person.

GENES · Several years before Mendel's death, scientists had discovered and studied chromosomes.[1] They thought it likely that these had something to do with the inheritance of characters. Later the presence of minute bodies in the chromosomes was discovered. These bodies were given the name of genes*[2].

Genes are estimated to be less than one billionth of an inch in diameter. Exactly what they are is not yet known. It is believed that they may be large protein molecules. But whatever they may be, they are known to be the determiners of heredity. They are arranged in a certain order along the length of every chromosome, somewhat like dots or grains of sand in a line (illustration, p. 483).

In every *body* cell there are two sets of paired chromosomes, and each chromosome has its line, or set, of genes.[3] Hence there is a pair of genes for every character that an organism has—a pair for body color, another for height, and so on (illustration, p. 483, inset).

In the process of forming sperms and eggs by reduction division,[4] two sets of chromosomes separate. Therefore each *sex* cell has only one set of chromosomes and one set of genes.

When a sperm from one individual unites with an egg from another, each of these two sex cells contributes a set of chromosomes and consequently also a set of genes to the fertilized egg. Hence this fertilized egg will contain two sets of paired chromosomes and two sets of paired genes, one set obtained from each parent. But the "string" of genes received from one parent is unlikely to be the same as that received from the other. For example, if one parent has a pair of dominant genes for color and the other parent a corresponding pair of recessive genes for color, then the offspring will have one dominant color gene (P or B) and one recessive color gene (p or b), which make a pair unlike that of either parent (Pp or Bb) (illustration, p. 479). Hence when all the characters are considered, the young plant or animal is sure to differ from each parent in some respects.

The illustration on page 484 shows the results of crossing each of two pure strains of chickens having two pairs of genes for each of two characters.

LATER DISCOVERIES WITH RESPECT TO MENDEL'S PRINCIPLES · Biologists, working with various plants and animals, have found some exceptions to Mendel's principles. It would be strange if they had not, for there are few biological principles to which no exceptions are known.

Some cases have been discovered in which the law of dominance seems not to operate. For example, when Correns,[5] a German botanist, carried on his experiments to check Mendel's results,[6] all the F_1 hybrid generation of purebred white-flowered and red-flowered

[1] Page 439.

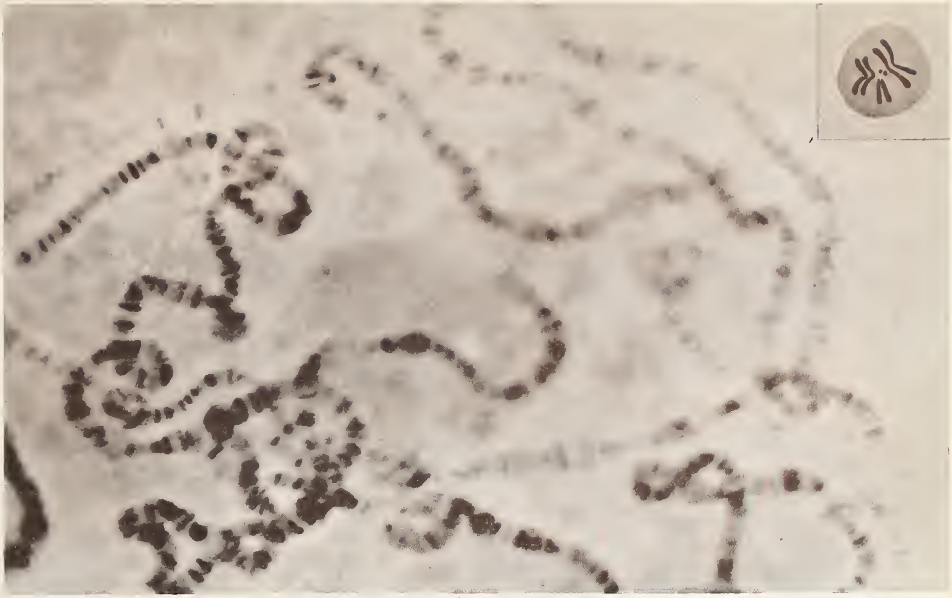
[2] *Gene* (jēn).

[3] The science of heredity is known as *genetics* (jē nĕt′ĭks). A biologist who studies the laws of heredity, or who applies them in securing new patterns of genes and hence in securing improved strains, is a *geneticist* (jē nĕt′ĭ sĭst).

[4] Page 439.

[5] *Correns* (kōr′ĕns); lived, 1864–1933.

[6] No. 3, p. 507.



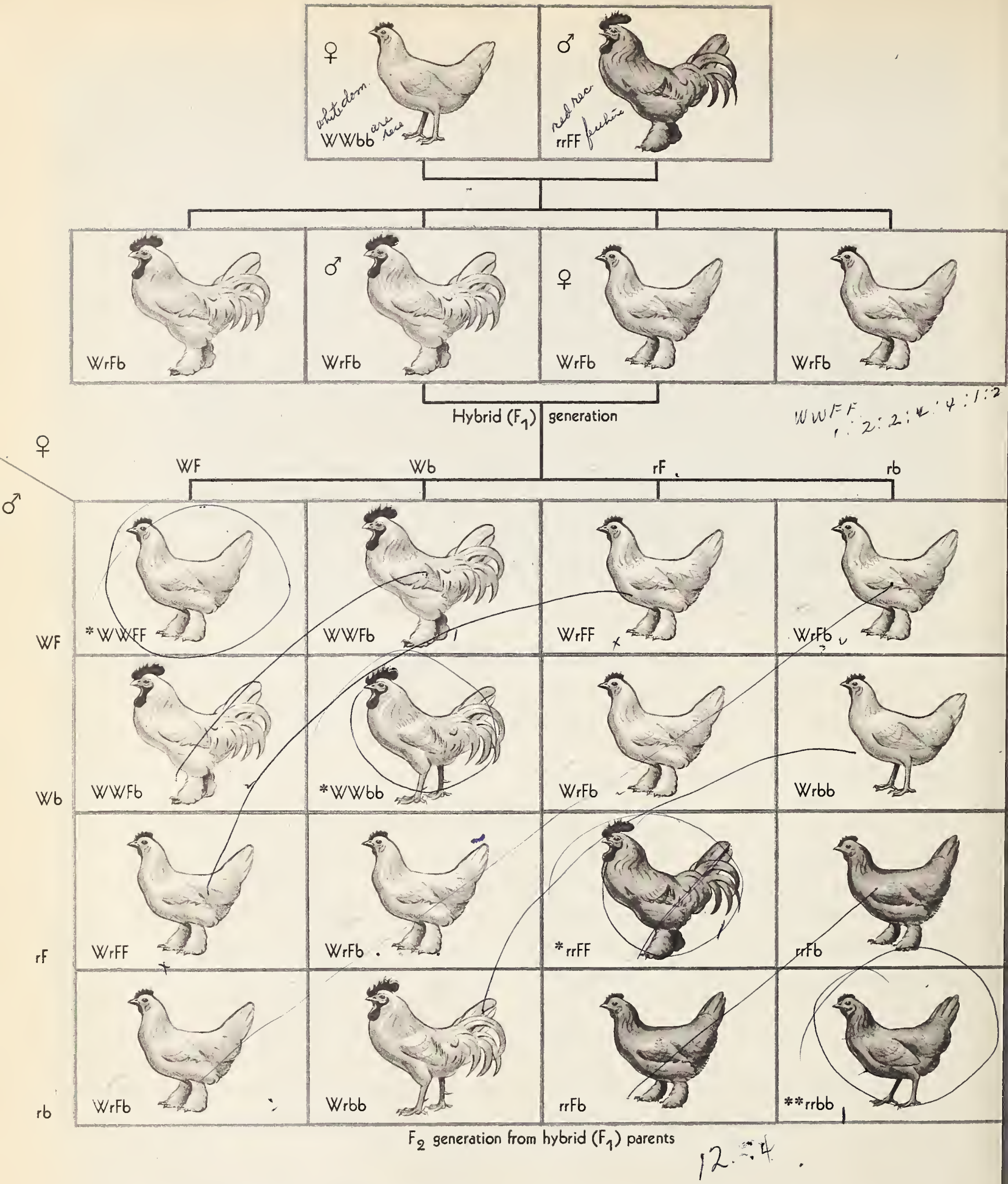
Chromosome mass in the salivary gland of a fruit-fly larva · The inset shows the eight chromosomes in a body cell of the fruit fly. How many pairs of chromosomes are there in every body cell of a fruit fly?

four-o'clocks had pink blossoms instead of either red or white ones. Chicken-breeders have discovered that all the F_1 hybrid generation of chicks produced by mating purebred black with purebred white Andalusian chickens have an "in-between blue" color.

Such hybrids are examples of what is now known as incomplete or imperfect dominance, or lack of dominance. In such cases the genes do not combine, as they appear to do, for genes never do combine. The hybrids have in-between characters because neither character is dominant over the other. Yet in other respects the Mendelian principles hold. Thus, in the F_2 generations grown from the hybrid (F_1) pink four-o'clocks and the blue Andalusian chickens, there were both red-flowered and white-flowered four-o'clocks and both white chickens and black chickens (principle of segregation).

What is apparently another example of imperfect dominance is often observed in the skin color of children whose parents are of different primary stocks.[1] The children have the skin color of neither racial stock, but instead have an in-between color blend, which varies in different children. This is not, however, a case of lack of dominance between the genes of one pair. The apparent blend of characters results from the joint effects of several pairs of genes, all of which, instead of just one pair, affect skin color. These pairs are present in different numbers in different

[1]Page 503.



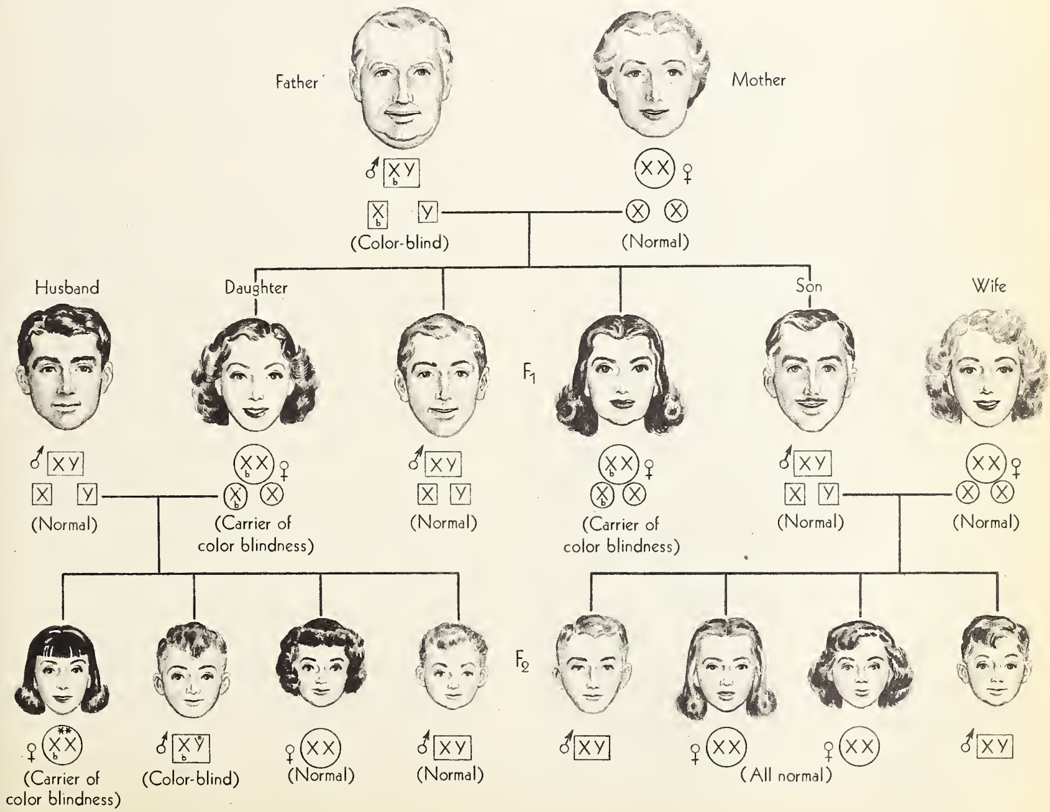
Two generations of chickens raised from two pure strains, each having two pairs of dominant and recessive characters · These characters are white (**W**) dominant, reddish-brown (**r**) recessive, and feathered legs (**F**) dominant, bare legs (**b**) recessive
Why do all the F_1 hybrids look alike, but not like either parent?

children. Thus one may have only one pair, and his brother or sister may have two or more pairs. Hence children in the same family may vary in their skin shades.

A number of other examples have been found in which the effects of certain genes have been modified in one way or another by the presence or absence of other genes. In fact, it is now believed that genes may often modify the effects of other genes even when the results cannot be observed in the offspring. Some geneticists believe that no character is determined by only one pair of genes, with no influence whatever from any other.

SEX-LINKED CHARACTERS · Are you color-blind, or do you know somebody who is? Perhaps you have trouble in finding as many wild strawberries among the green leaves as

A man who is color-blind marries a woman who is normal for this trait. Any daughters they may have will carry the gene for color blindness. Their sons will all be normal for the trait. The chances are even that the sons of these daughters will be color-blind or will not be. The chances are also even that the daughters of these daughters will carry the gene for color blindness or will not. Why will all the children of the sons be normal for this trait?



others do. Perhaps you have difficulty in selecting neckties or blouses that "go well" with whatever else you are wearing. Perhaps you are not sure whether a traffic light is green or red.

The commonest type of color blindness is the red-green type. About 4 per cent, or less, of boys and men cannot distinguish red from green, and about one half of 1 per cent of girls and women cannot. Somewhat less common is the blue-yellow type of color blindness. Some persons cannot tell any color from any other, but such an extreme form of color blindness is exceedingly rare.

These snapdragons were offspring of similar parents, but the seed that produced the one on the right was treated with colchicine. Does such a use of colchicine seem to you to hold possibilities for increasing the world's food supply? Explain

W. Atlee Burpee

Older men are usually more or less bald, but older women rarely are.

Color blindness and baldness are examples of sex-linked characters. The genes for these characters appear to be dominant in men and recessive in women. Hence a girl or a woman could be color-blind or become bald only if her father had the character, and if also her mother had at least one gene for it. A boy or a man, however, might have either of these characters if his mother's father had them (illustration, p. 485).

Sex-linked characters of some kinds are found among plants and many more among animals. Thus it is possible, as soon as certain kinds of chicks are hatched from the eggs, to tell by their color markings whether they are roosters or hens. Many sex-linked characters have been found among fruit flies. In the generations produced by certain crossings, the males always have one eye color or body color and the females another.

In some cases of sex-linked characters, one sex will appear to have only one character that the other does not have. In other cases there may be several characters that are always found together in one sex and are always absent in the other. In such cases a male or a female either has all of the group or has none of them.

Sex-linked characters are those whose genes are in the X chromosomes, which determine sex, but are not in the Y chromosomes.[1] In other words, the X chromosomes carry not only genes that influence sex, but also genes for many other characters. Usually only one of the X chromosomes has a sex-linked gene. To illustrate with color blindness:

If, in the process of the fertilization of the

[1]Pages 439–442.

egg, the X chromosome with the gene for color blindness pairs with the Y chromosome (F_1, illustration, p. 485), then the boy that develops is color-blind (*F_2, illustration, p. 485). If the X chromosome with the gene for color blindness pairs with a normal X chromosome, the girl that develops is not color-blind (**F_2, illustration, p. 485). She could, however, pass this gene on to her son, who would be color-blind.

At the time that fertilization takes place, therefore, not only is the sex of the offspring established, but any characters that always appear in one sex, but not the other, also are.

THE Rh BLOOD FACTOR · Not only are there four groups of human blood,[1] but in addition there are so-called "blood factors." One, the Rh factor, is so named because it was first discovered during certain extensive experiments with rhesus monkeys. These factors are inherited characters, which are controlled by genes, as are all inherited characters.

About 85 per cent of people have Rh+ blood, and the remaining 15 per cent Rh–. Both factors are normal, and neither is superior to the other any more than a right-handed person is superior to a left-handed one. It is only when Rh+ and Rh– blood are mixed in the blood stream, as in a whole-blood Rh+ transfusion, that there is danger. Whenever that occurs, the blood of the receiver manufactures antibodies (agglutinins[2]). In time, when enough have accumulated, these destroy the red blood corpuscles of the blood received from the donor. In such cases serious or even fatal consequences may follow, if there have been previous such transfusions.

The child of an Rh+ father and an Rh– mother may have Rh+ blood because the genes for the Rh+ factor are dominant over those for the Rh–. If it does, as the embryo develops, antibodies formed by the mother's blood destroy its red corpuscles. Often the baby dies before birth, and even if it does not, the results are usually serious both to the child and to the mother. Such cases occur, however, only once in three hundred or four hundred births.

An increasing number of people are having their blood tested not only for the four types, but also for the Rh factor. Such knowledge is valuable not only to married people, but to everybody else as well, because an accident or an illness may make it necessary for a person to give or receive a whole-blood transfusion.

MUTATIONS AND GENES · Variations between one generation and the next are caused by changes in the number of chromosomes or of genes within cell nuclei. The changes may be brought about by either gains or losses of chromosomes or genes, or by new arrangements of genes. They may be great or small. They occur naturally, of course, but the most striking changes of this sort have been produced by artificial means.

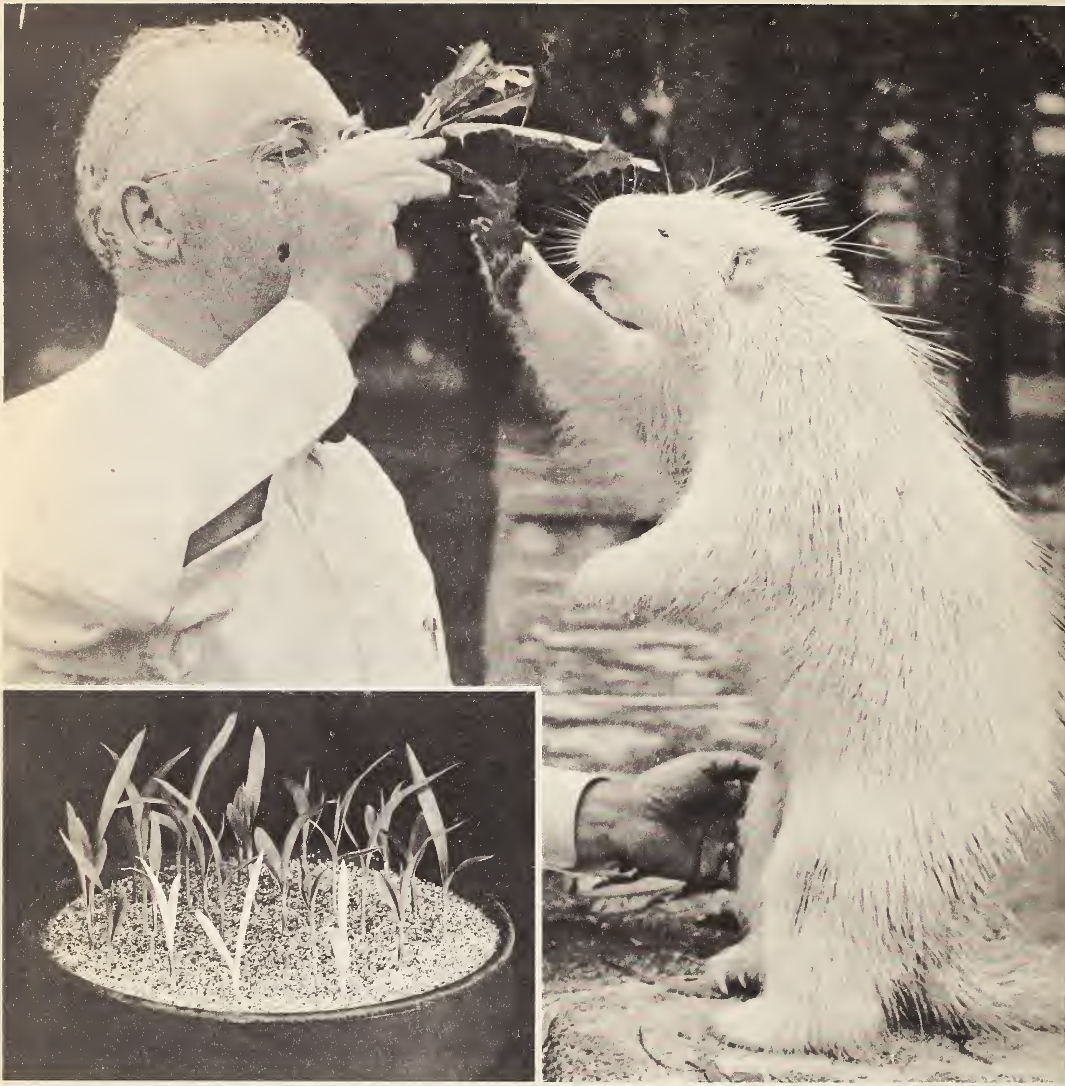
Fruit flies have been caused to produce mutants about one hundred and fifty times as frequently as they normally do, by being exposed, as adults, to X rays. X rays have produced mutants also in plants, but usually they kill plants. Sudden changes to considerably higher or lower temperatures sometimes produce mutant plants or animals.

In some instances certain chemical substances, fed to insects in their food or put upon plants, have produced mutants. The most striking effects of this latter sort are produced by the drug colchicine,[3] obtained from the bulbs of the autumn crocus. When it is applied in diluted solutions to germinating

[1] Footnote, p. 253.

[2] Page 308.

[3] *Colchicine* (kŏl′chĭ sēn).



Brooklyn Botanic Garden; Press Association

Albinism is the general term applied to a lack of color in the leaves of a green plant or in the fur or feathers and the eyes of animals. White rats, white mice and this porcupine are albinos, but polar bears and snow-shoe rabbits are not. Explain

seeds, bud tips, or seedlings, it causes the numbers of chromosomes within the nucleus of each cell to double. Hence mutants in unusual numbers appear. The resulting plants, moreover, are usually larger and more vigorous, and have greener and thicker leaves and bigger flowers (illustration, p. 486).

The artificial variations brought about by

colchicine are so great as to be produced rarely, if ever, by natural processes.

Colchicine is poisonous to animals. Hence whatever effects it might have on animals' chromosomes cannot be determined.

MUTATIONS PRODUCED ASEXUALLY · As would be expected, mutants result most frequently from sexual reproduction, but they do arise sometimes in asexual reproduction. Occasionally they occur in the process of vegetative growth. For example, one of the limbs on a green-apple tree recently produced red apples that ripened earlier than the rest of the fruit. A commercial nursery bought this one limb for six thousand dollars. From it the nursery propagated an excellent new variety of apple by the process of grafting.[1]

Mutations arising from asexual reproduction, as well as those from sexual reproduction, result from changes in the chromosomes and genes.

GENES AND SURVIVAL · The genes that an organism inherits may increase or decrease its chances of survival. For example, the presence of genes that cause a rapid growth of leaves may so greatly increase the food-making ability of a plant that it will survive while others around it starve. In contrast, if a plant fails to inherit the genes that cause the making of chlorophyll, as sometimes happens, then, after it has sprouted from the seed, it will live only as long as is required for it to use up all the food stored in the cotyledons (illustration, p. 488). The possession of genes that bring about a protective resemblance[2] may cause an animal to escape predators longer than it otherwise could. Thus it may have more than the normal number of offspring, and they may inherit these genes. The absence of genes for color in an animal may result in its being captured by a predator soon after its birth (illustration, p. 488).

Sometimes an organism has genes that produce defective offspring. Such genes influence the development of the offspring in accordance with the Mendelian principles, just as other genes do. Common examples of characters produced in human beings by such genes include hemophilia[3] (failure of wounds to stop bleeding), color blindness, and certain types of feeble-mindedness, insanity, and deafness. Among wild animals dominant genes that produce defective young tend to be eliminated because the individuals possessing them usually die or are killed before they can become mature and produce young.

Some sex-linked genes cause the death of an organism during its development as an embryo. Such genes are known as lethal,[4] or death-causing, genes. Some of these cause the death of the males, even if only one is inherited. If a pair of them is inherited, the embryo always dies. More than forty of these lethal genes have been found and studied in fruit flies. They have been discovered also in mice and a few other animals.

3. How May Living Things Be Improved?

It is believed that probably the first animal domesticated by man was the dog. At any rate, the dog has been a companion of man for thousands of years. Proof of this fact is provided by the bones of dogs that have been

[1]Page 433.

[2]Pages 203 and 545. [3]*Hemophilia* (hē mō fĭl'ĭ *ȧ*). [4]*Lethal* (lē'thăl).

found along with those of Stone Age men. Also, there are references to dogs in many ancient historical records. For example, there are pictures of dogs on Egyptian monuments built about five thousand years ago. Dogs are mentioned in the Old Testament. Ancient Greek records reveal that in 450 B.C. a Greek general (Alcibiades) paid the equivalent of more than one hundred thousand dollars for a dog (illustration below).

It is known that as long ago as the early Roman Empire the people had sheep dogs, watch dogs, and hunting dogs. Moreover, they had developed separate breeds of hunting dogs, those that were especially keen of scent and thus able to track game, those that were fleet and hence could overtake their quarry, and those that were fierce fighters.

Dogs are believed to have originated from the wolf, the fox, and the jackal. There is now probably no other mammal that varies so much in size and perhaps in appearance as the dog. What question or questions come into your mind when you see this picture?

International

THE METHOD OF SELECTION · The Romans produced and improved their varieties and breeds of dogs by the method of selection. They probably used also the method of inbreeding. The method of selection includes (1) using as parent animals and plants in each generation the ones that have the desired characters most strongly evident, and (2) preventing the less desirable individuals of each generation from reproducing.

This method of selective breeding is still the one most commonly used. Farmers today keep the seeds of the best plants of many kinds for the next year's crops. Also, they improve their herds with the best stock available.

Offspring generally resemble their parents more or less closely. Yet improving plants and animals by selection alone is likely to be a slow and discouraging process. To begin with, the individuals selected for crossing are likely to be hybrids with widely different sets of genes. Consequently, when they are crossed, their offspring may not show the desired character to a marked extent and may show other characters that are highly undesirable.

THE METHOD OF INBREEDING · Inbreeding is the breeding of closely related individuals. Plants that self-pollinate inbreed naturally. Plants with separate male and female flowers on the same plant—for example, melons, squashes, and corn—can be inbred in this way: Pollen from the male flowers is put upon the pistils of the female flowers. The latter are then "bagged"[1] (covered) to prevent their receiving pollen from any other plants. Plants can be inbred, also, by cross-pollinating offspring of the same parents, such as the hybrids of the F_1 generation, members

[1]Page 478.

Joe Clark

A mule is the hybrid offspring of a male donkey and a female horse. It is one of the most valuable of all hybrids. How many reasons can you give why it is?

of the F_1 and F_2 generations, or other near relatives.

Like the inbreeding of plants, the inbreeding of animals is accomplished by mating the offspring of the same parent, or offspring and their parents, or other closely related individuals.

RESULTS FROM INBREEDING · The two sets of genes inherited as a result of inbreeding are either almost entirely alike, as in the self-fertilization of plants, or nearly alike, as in the crossing of related plants or animals. Hence two identical genes of the desired character—for example, the early ripening of fruit or the earlier maturing of animals—are almost sure to become paired. If this does not happen in the first inbred generation, then it can be expected to occur in a later one.

Whenever this occurs, the character which these genes control becomes pure in the strain. In such cases the crossing of related individuals results in improving the strain.

Crossing related individuals, however, can result in a less desirable strain. Identical undesirable genes, as those producing "runty"

plants or animals, become paired by inbreeding, just as do the desired ones. Such genes are usually recessive. Therefore, when paired, they produce a pure recessive strain. This is the reason why the offspring produced by inbreeding often become less vigorous and often more abnormal in each succeeding generation, as more identical recessive genes become paired. Such loss of vigor is more marked in the first inbred generation because more recessive genes usually become paired in that generation than in later ones.

Luther Burbank holding a tropical bulb which he obtained for experimentation · Burbank was America's most celebrated plant geneticist half a century ago. He used the methods of selection, hybridization, and inbreeding with success long before he had heard of Mendel's work. He did not use the modern method of breeding to produce hybrids as the final and desired product, because he did not know this method. **Topic for Individual Study:** The Work of Luther Burbank

Brown Brothers

THE METHOD OF HYBRIDIZATION · Hybridization is the opposite of inbreeding because it is done by the cross-pollination or cross-fertilization of different strains (illustration, p. 491). Its purpose is to bring together different characters in the offspring. This it accomplishes because the eggs and the sperms that unite to produce hybrids have sets of chromosomes and genes that are almost certain to be widely different.

The hybrid offspring of purebred parents usually have what is called "hybrid vigor," or increased vitality. Hybrid vigor manifests itself in the superiority of the hybrid in various respects, such as increased yield, better quality of yield, larger size, heavier weight, or better resistance to disease or unfavorable conditions in the habitat. Thus, as plant and animal breeders have recently discovered, hybrids are often superior to purebreds.

Hybrid vigor is greatest in the F_1 generation. It often is marked even in the F_1 generation produced by crossing weakened pure strains that have resulted from several generations of inbreeding.

MODERN METHODS OF PLANT AND ANIMAL IMPROVEMENT · The plants and animals that are native to any locality are likely to be well adapted to it. Those that have not been able to withstand its diseases, its climate, or other unfavorable factors have died off, leaving only the well-adapted ones as survivors. When, however, man makes his home in a new locality, he brings with him his domestic plants and animals. These often prove to be unsuited to the new habitat. Hence they

either die or fail to produce their usual desired products.

Geneticists are constantly and successfully trying to develop superior strains of domestic plants and animals that can survive and function effectively in new localities. They are engaged also in producing better strains to replace or supplement the present ones.

The modern geneticist uses the methods of selection, inbreeding, and hybridization used by Mendel and Burbank (illustration, p. 492). But he has gone far beyond the work of these men. He has extended some of Mendel's principles and has modified others in accordance with the facts discovered. He applies his exact knowledge of the principles of heredity and thus achieves the desired goals with a minimum of time and effort. Even then the process is neither brief nor easy. Many years of careful work are required in practically every case.

The modern breeder is able to produce a strain of plants or animals that possesses almost any combination of characters that are found in individuals or in related species. He works directly to produce plants and animals with special characters or for specific uses, of which the following are examples:

1. **Immunity to diseases.** Many garden plants that are of high quality and also that can resist the attacks of fungus and other parasites have been established by crossing desirable strains that are not disease-resistant with other, less desirable strains that are. Strains of high-grade domestic cattle which are immune to diseases that formerly killed great numbers have been produced by crossing domestic cattle with disease-resistant Asiatic species.

2. **Adaptation to colder, warmer, more arid, or more humid regions than existing strains can endure.** Marquis wheat, developed by two Canadian geneticists, will grow and produce abundantly much farther north than other kinds. Crossing Afrikander cattle, an African breed, with our domestic breeds is expected to develop high milk-producing and beef-producing strains that can endure the hot, moist climate of the Gulf states better than our domestic cattle can.

3. **Increased yields of desired products, such as seeds, butter-fat, eggs, vitamins, starch, and lard.** The champion of a milk-producing strain of cattle has produced nearly forty-two thousand pounds of milk in one year. A strain of yeast has been developed that has a pleasant flavor and a high content of protein and of vitamin-B complex. During the Second World War this yeast was used in great quantities for the Allied armies and for Lend-Lease. Since the war it has been one important means of reducing starvation in the war-ruined countries of Europe and in China.

4. **Unusual size or color, long hair, fragrance, flavor, etc.** A bush pumpkin and a watermelon, both developed especially to grow in a small, back-yard garden plot, have been recently perfected. Each of these plants produces small but superior fruit. Draft horses and race horses are examples of the successful breeding of different qualities into the same kind of animal.

A MODERN PROBLEM IN GENETICS · About twenty years ago two diseases, wilt and rust, were threatening to exterminate the tomato crops in certain localities. The Marglobe tomato was developed by the United States Department of Agriculture to meet the need for a tomato plant that would bear abundant fruit of superior qualities and would be resistant to those two diseases. This fine, improved variety saved the tomato industry. Yet it is not completely resistant to wilt. The problem, therefore, was to produce an equally good tomato that would be.

Forsythe, from United States Department of Agriculture

The geneticist is holding the Pan American tomato. The plants from which this tomato was developed are the Marglobe, at his right, and the berry-like tomatoes in front of him. A century ago tomatoes were called "love apples" and were believed to be poisonous. The vines were grown only as ornamental plants. To which of the items under "As Scientists Think" are these last two statements most closely related?

SOLVING THE PROBLEM · An American geneticist undertook to produce such a plant. He searched the world for a species of tomato that was completely wilt-resistant. Finally he found, in the Andes Mountains of Peru, a wild "currant" tomato which had this character. Its fruits, however, were only about as large as cherries and of poor quality.

The geneticist crossed the Marglobe with this wild tomato. The F_1 hybrids inherited wilt-resistance from the wild parent. Unfortunately, however, they inherited also its small fruit and poor quality. The geneticist crossed the F_1 hybrids. From the F_1 generation he selected the wilt-resisting plants with fruit of largest size and best quality.

He continued selecting and cross-breeding the hybrids of each generation. Finally, after raising about eighty thousand tomato plants, he had four plants that combined in their genes all the desired qualities of the Marglobe ancestor, together with the wilt-resistance of the wild progenitor (ancestor). From these plants he finally obtained by cross-breeding a pure strain having all these characters. This strain is the Pan American (illustration on this page).

MODERN HYBRIDIZING · How the modern plant-breeder can combine four desired characters into one strain may be illustrated with hybrid corn. Suppose that in a corn-field there are (1) plants with an unusually large number of ears, (2) others with uniform, well-filled ears, (3) others with strong stalks, and (4) others with the ears at a convenient height for machine harvesting. A hybrid strain of corn plants, every one of which will have all these four characters, can, if all "goes well," be produced in eleven years. In each of these eleven seasons, each crop of corn that is grown for the purpose of producing the desired strain must be planted at least six hundred feet from any other corn plot. This must be done in order to prevent cross-pollination of the ears by wind-blown pollen from undesired strains.

For convenience in describing it, the task of producing the desired hybrid strain may be

divided into four successive[1] stages, or parts: (1) producing four *pure* strains of corn each of which will have one of the desired characters (illustration, Stage I, p. 496); (2) producing from the four pure strains two *hybrid* strains each of which will have two of the desired characters; (3) "fixing" in one *pure* strain the two desired characters of each of these hybrids; and (4) combining the resulting two pure strains into a *hybrid* strain which will have all four of the desired characters.

How the four parts of the projects are carried out is described in the following paragraphs:

1. Producing the four pure strains. Seeds from any corn plants having the same one of the four characters are planted in one plot. Seeds from the plants having each of the remaining three characters are planted in similar plots. Thus four separate growing projects are being carried on at the same time.

The method of propagation used is inbreeding.[2] The inbreeding of each strain is accomplished by hand-pollinating the female flowers (corn silk), which are on the ears, with pollen from the male flowers of the same plant, which are at the top of the plant. All the male flowers in the field must be bagged to prevent cross-pollination.

After seven successive years of such inbreeding, the desired characters will be fixed in four separate strains.

2. Producing two hybrid strains, each having two of the desired characters. Each of the four pure strains already produced has one of the desired characters, but it may have other characters that are not desirable. Thus the plant with the large number of ears may have small and poorly filled ears. The plant with the uniform, well-filled ears may have only a few of them.

Therefore, in the next year, two of the pure strains are cross-pollinated in each of two separate plots. To illustrate: In one plot the strain with the large number of ears may be cross-pollinated with the strain having the uniform, well-filled ears. In the other plot the strain with the strong stalks may be pollinated with the strain having the ears at a convenient height for harvesting. Thus, in the second stage of the task, two separate growing projects are being carried on at the same time.

The method of cross-pollination used is the same as that used by Mendel in producing his F_1 generation (illustration, p. 479). The desired result is accomplished in each plot in one season. Thus, at the end of the eighth year from the beginning of the task, a *hybrid* will be obtained which will have two of the desired four characters.

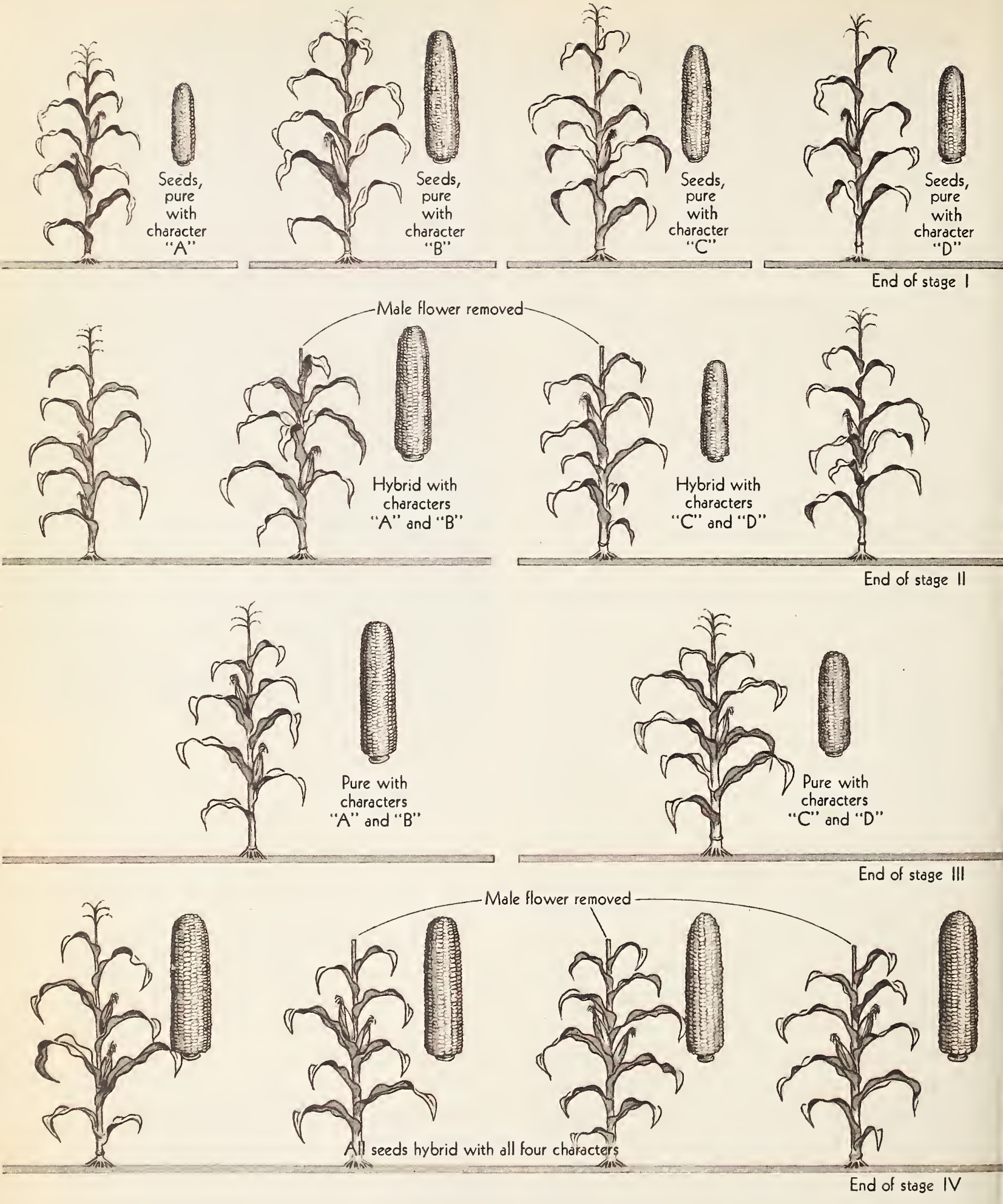
3. Fixing in one pure strain the two desired characters of each hybrid. Each of the two hybrid strains obtained from the second stage is inbred by self-pollination for two more consecutive years. The method employed is the same as that used in the first stage. The desired result will be accomplished at the end of the tenth season from the beginning of the project.

4. Producing the hybrid strain which has all four of the desired characters. In the eleventh, and final, season the two pure strains resulting from the third stage are cross-bred in this way:

The two pure parent strains are planted in the same plot, in the ratio of three rows of one strain to one row of the other. The plants in the three rows, which may be of either strain, will have their male flowers removed. Hence they will function only as female plants. The plants in the one row will be left as they are

[1]*Successive* (sŭk sĕs′ĭv), or *consecutive* (kŏn sĕk′ū-tĭv): following in a regular order which is not broken or interrupted.

[2]Page 490.



How hybrid corn with four desired characters is produced · What do you think was the purpose of putting this illustration here?

and hence will serve both as males and as females.

In July, when the male flowers at the tops of the plants that are to function only as females begin to develop, they are removed by workers who ride between the rows on high-wheeled platforms. With these sources of pollen destroyed, all the ears on the female plants, and on the male-and-female plants as well, are wind-pollinated only by the pollen from the rows of the latter (illustration, p. 496).

The seeds in the ears of all the plants will have paired genes for the four desired characters, namely, (1) many ears, (2) uniform, well-filled ears, (3) strong stalks, and (4) ears all growing at the right height for rapid commercial harvesting. The kernels of this hybrid corn can be sold as seed with a guarantee that they will produce crops having the four characters.

Hybrid corn has great hybrid vigor because in it several dominant pure strains are brought together. Hence it commonly yields many more bushels to the acre than any of the strains from which it has been bred. It is likely also to be superior to them in other ways.

HYBRID PLANTS AS PARENTS · The seed of hybrid-corn plants is not saved for planting. It would not produce a similar crop the following year. If such seed were planted, the resulting crop would show variations of the desired traits, just as the children in a family may resemble one or another grandparent or even a more distant progenitor. The corn-grower must buy hybrid seed every year. But this seed, which ensures a uniform yield with certain guaranteed characters, costs only a small fraction of what the returns from the crop will be. It is no wonder, then, that in the "corn belt" nearly all the corn now grown commercially is hybrid corn. Today the production of hybrid-corn seed with various combinations of desired characters is a great industry.

If you will examine any flower-seed catalogue, you will find in it many hybrid plants listed for sale. These have been developed by methods similar to those used in producing hybrid corn (illustration, p. 496). They will have the qualities advertised. But if you were to save the seed from these plants, and should plant it the next year, you would have probably only an occasional plant, or perhaps not any, like the hybrid parent (illustration, p. 498). Hybrid plants can be made to breed true, however, if they are reproduced by bulbs, grafts, or other methods of asexual reproduction.[1]

Many plants that are not closely enough related to be crossed by ordinary methods can be crossed by the use of colchicine.[2] Furthermore, many hybrids that are normally sterile (unable to reproduce) can reproduce when treated with this drug.

NATURE AND MAN · Nature carries on its processes without consideration of man. At the same time that man is trying to produce improved strains of plants and animals, new strains are also constantly being produced by natural processes. One of these naturally produced strains sometimes undoes many years of patient and careful work by plant geneticists. An example is furnished by crop plants and some fungus diseases that attack them. Plant-growers may spend years in producing a strain of food plant that will resist rust. Finally they succeed. But before the new strain can be produced in large enough quantities to be generally valuable, it is attacked by a new kind of rust to which

[1]Pages 430–434. [2]Page 487.

it is not resistant. This new rust may be a mutant of the old rust plant.

The improved varieties of plants and animals that geneticists produce are not really "new." They are not new in the sense that they are unlike anything else that ever lived. The geneticist by his breeding methods merely rearranges the genes that already exist, so that new patterns result. Thus the strains he produces have some characters that are not found in their relatives.

The geneticist can work only with the characters already present in the organisms. He cannot produce new genes. There are standing offers of large sums of money for certain kinds of flowers with unusual colors. But these prizes have never been claimed and probably never can be, because the genes for the desired colors are not present in any of the known species.

The dwarf, double French marigold at the top was crossed with the tall, double African marigold at the bottom to produce the hybrid at the upper right. If plants were grown from the seeds of the hybrid plant, what sorts of flowers should you expect would be found on them? Explain

W. Atlee Burpee

INFERIOR AND SUPERIOR HUMAN STOCKS · **An inferior family.** In one state there is a community that fortunately is almost unique. A majority of its members are defective in one way or another (illustration, p. 500). The community was started many years ago by a man whose fingers lacked the usual number of bones. He married; and since the genes for this character are dominant, his children inherited it. Through these children and their descendants, the defect has been passed on.

The people outside the community who have married these defective persons of different generations have, in many cases, themselves been inferior in intelligence and in other respects. Highly intelligent and otherwise superior people do not, generally, marry into families known to be defective. From these inferior "outsiders" genes for insanity, feeblemindedness, and other undesirable traits have been added to those of the original defective strain. There has been much inbreeding through cousin marriages within the community.

[E]Cousin marriages do not necessarily result in defective children. Some noted families owe part of their greatness to cousin marriages. In such cases, however, both the related parents possessed the genes of the same desirable characters. But there is always the danger that a person may have an undesirable recessive gene which does not show. If such a person marries somebody, whether a relative or

a non-relative, who has the same undesirable gene, the undesirable trait related to this gene may appear in their children.

[E]Marriages of relatives are therefore to be avoided because cousins and even more distant relatives are more likely to have recessive genes for the same characters than are two persons not related. Hence laws prohibiting cousin marriages are sound laws because the results of such marriages are, in the majority of cases, more likely to be bad than good.

In the case of the community under discussion, inbreeding by marriages of relatives has resulted in bringing out defective characters by pairing in the children undesirable recessive genes received from both parents.

The community is now several generations old. It is really one family, since it is composed almost entirely of people who are more or less closely related. This family is a constant and growing burden upon the rest of the people of the county, who must support many of its members with charity and through taxation.

A superior family. In contrast with this family are the descendants of Jonathan Edwards, a prominent American minister, who lived about two hundred years ago. The life histories of nearly fifteen hundred members of the family that he founded have been studied. These people were the children of unions of the Edwardses, who were a superior group, with superior men and women of other fine families. There were also some marriages of cousins and second cousins. In each generation there was good heredity on both sides in a majority of the marriages in this family, just as there was the opposite in the marriages within the inferior family.

More than one fourth of the members of the Edwards family have been distinguished to a greater or a smaller degree. Practically all the rest have been well above average in abilities and achievements.

These two families demonstrate what all geneticists know, namely, that the principles of heredity operate in people in just the same ways that they operate in other organisms (illustration, p. 501). As a result, different human beings vary not only in physical characteristics, but also in mental, emotional, moral, and all other traits.

WHAT MAKES PEOPLE INFERIOR OR SUPERIOR, HEREDITY OR ENVIRONMENT? · [E]There are two factors that mold human beings, just as they mold all other living things. These factors are heredity and environment. These are often called "nature and nurture." Environment, or nurture, includes many factors, such as the kinds and abundance of available food; the kind of home and neighborhood in which an individual lives; the kinds of people with whom he associates; the churches, schools, and other social agencies available to him.

Environment is just as important, of course, in the development of every other living thing as it is in that of man. For example, the finest hybrid-corn seed ever produced would never even sprout if it were planted on an ocean beach. A polar bear that spends all its life in a zoo will never become a predator of seals, walruses, and fish.

"NATURE OR NURTURE?" · The question is often asked, "Which is the more important, heredity or environment?" There can be no satisfactory answer to this question, really, because "nature and nurture" can never act separately upon an individual. Heredity determines what it is possible for a person (or other organism) to do or to become. Environment determines whether he will have the chance to develop his abilities. For ex-

An investigator states that at least 25 per cent of those in our jails and prisons are mentally defective

Another investigator found that 67 per cent of the boys and girls in one reform school had less than normal intelligence

Feeble-mindedness and a tendency to be insane, epileptic, or criminal can be inherited. So also can superior traits, such as high intelligence, and musical, artistic, and other abilities. Which of the undesirable traits here mentioned do you think might sometimes also result from habit-forming drugs, or from disease, injury, or other unfavorable condition resulting from the environment? Your family doctor or a psychiatrist[1] could supply the answer to this question

ample, it may be possible for a boy to become a successful lawyer or a good shop mechanic, because he has inherited genes for high intelligence and other traits which a lawyer needs, on the one hand, or those for good muscular control and other traits which are necessary for a mechanic, on the other. Whether he becomes the lawyer or the shop mechanic, however, depends on whether his environment provides him with the necessary opportunities for study or for developing his mechanical abilities and skills.

To illustrate further how heredity and environment affect human development: There is no doubt that the members of the defective family, described on pages 498 and 499, had poor heredity and that the members of the Edwards family had excellent heredity. Yet probably even the best people have some genes for undesirable characters. And even the worst have some genes for desirable characters. In other words, it is probably possible for anybody to be either better or worse in some respects than he is.

The first family always had a bad environment. The second had, for the most part, a highly favorable one. These environments could not fail to affect the development of the individuals, any more than could their hereditary genes. Thus one family was the product of bad heredity and bad environment, and the other the product of good heredity and good environment.

PROBABLE EFFECTS OF EXCHANGING ENVIRONMENTS · Let us suppose that, after a generation or so, the two families had exchanged environments. Would the first family have become superior, as the Edwards family did become? Would the Edwards family have sunk to the present level of the other family?

[1]Page 336.

Without doubt the answer to both questions is "No." Many members of the inferior family—for example, the idiots and insane members—would have been defective even under ideal conditions. But there is little doubt that, in a good environment, more of the members of that family would have lived useful and successful lives than did in the bad environment. It seems reasonable to believe, moreover, that many members of the Edwards family would have risen above a bad environment. But it is not likely that there would have been so many who were superior. The two families would no doubt still have shown a marked contrast. But their differences would surely have been less great than they now are (illustration, p. 502).

PERSONAL CONDITION · Sometimes a person's failure is due neither to poor heredity nor to bad environment. Many people who seem lazy and "worthless" are so because they are not well nourished or because they are ill. They may, for example, be suffering from hidden hungers[1]; they may lack essential hormones[2]; they may be infected with malaria, hookworm, or other disease parasites; or they may be over-worked. When such conditions are remedied, the persons often are able to take their places as substantial and valuable members of society.

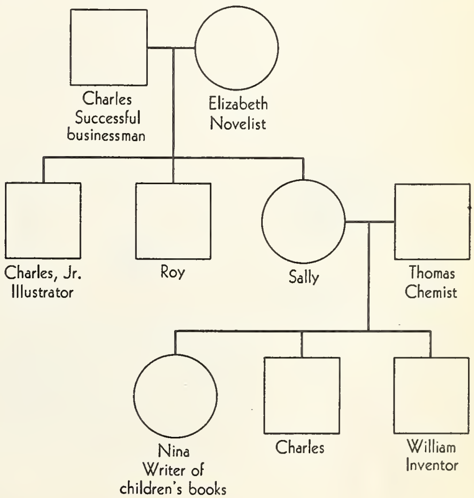
POST-WAR ASPECTS · At the end of the Second World War millions of people in Europe and Asia were suffering from bad environment and from individual ills brought about by the war. They did not have enough of the right kinds of foods, they lacked proper medical care, their cities were without proper sanitation, their homes and communities had been destroyed by bombing and shell fire. No doubt you could add other unfavorable factors to this list. In spite of all efforts to remedy such conditions, they are certain to continue to exist, at least in part and in some localities, for many years. Their effects upon future generations will last for centuries. Some of these effects may never be wholly overcome.

[1]Pages 92–94. [2]Pages 290–293.

ACQUIRED CHARACTERS NOT INHERITED

There is a rather common belief that what a mother does or experiences before her child is born is likely to affect the characteristics of the child. People sometimes speak of a "marked" baby. Suppose that before a child's birth the mother is bruised or burned. If then the baby happens to have, on the corresponding part of its body, a birth-mark that looks somewhat like a bruise or a burn, somebody is likely to think that the result of the accident to the mother was inherited by her child. Some people believe, too, that

Three generations of a superior family · Charles, Jr., and William were eminent. What does the evidence here indicate?



if a woman is badly frightened before her child is born, as by a fire or an animal, the child will be born with a fear of fire or of that animal. Many people believe, also, that a mother can give her child a lofty character by thinking only noble thoughts during the period before it is born, or that she can make the child talented if she herself undergoes the right training during that period. For example, they think that she can develop in her child a talent for art, music, or writing by looking at fine paintings, listening to good music, or reading poetry and fine prose.

There is no scientific evidence to support any of these beliefs. On the other hand, there is abundant evidence that acquired characters—that is, changes in structure which result from experience—are not inherited by an individual's offspring. For example, men have been having their hair cut for centuries, but it still grows as it did a thousand years ago. Formerly it was a common practice for women to have their ears pierced for earrings, but there is no record of any child, even a girl, who has been born with pierced ears. Everybody knows that the children of parents who have lost arms or legs are not born lacking these limbs. Doubtless you can think of other similar examples that involve not only people, but also domestic animals.[1]

As has been stated, an individual's possibilities depend on the pattern of his chromosomes and genes. This pattern becomes fixed at the time an individual begins life, that is, at the time when a sperm unites with an egg and forms an embryo. Changes can later occur in the mother's muscle cells, neurons, bone cells, or other body cells as a result of accidents, study, exercise, or other conditions. But such changes cannot affect the pattern of the genes of the developing child

Recent experiments indicate that changes can be made in the chromosomes and genes of sex cells by X rays[2] and in the body cells of some developing plants and insects by chemicals.[2] Such changes produce individuals markedly different from their parents. But such extraordinary cases do not change the principle that acquired characters are not inherited.

[1]Page 506, No. 2 ("Applying and Extending What You Know"). [2]Page 487.

Can you explain how "nature and nurture" apply in each of these pictures?

RACIAL DIFFERENCES · All human beings belong to only one species, *Homo sapiens*[1] (illustration, p. 504). Within this species there are three primary stocks (Negroid, Caucasoid, and Mongoloid). Each of these stocks includes several races. The Caucasoid stock, for example, includes the North European (Nordic), the Alpine, the Mediterranean, and the Hindu races. Nations include groups that represent often all three of the stocks and usually several races.

AMALGAMATION · Ever since people have been on the earth, different groups have amalgamated; that is, they have combined and fused with other groups whenever they have come in contact with them. The greatest changes in human groups have resulted from amalgamation following migration and conquest. A recent example of such amalgamation of different peoples is provided by the marriages of thousands of the men of our armed forces with women of Australia, New Zealand, France, England, Italy, and other nations during and after the Second World War. Similar marriages occurred in great numbers following the First World War.

As a result of the continuous (never-ceasing) amalgamation of peoples of different countries, and of individuals of different racial stocks within countries, all races and all nations are of mixed racial stock. The individual people have enormous variations in the patterns of their genes. Even where a group is distinct enough so that it can readily be identified as belonging to one stock or race, its individual members are certain to be of mixed racial stock. They always have many characters that are found also among other similar groups.

One major cause of the Second World War was the belief of the Germans and the Japanese that they were superior to other peoples and that therefore they should conquer and rule the world. Scientists, however, have never been able to find evidence to prove that any race is either superior or inferior to another in body form, intelligence, sense perception, or, in fact, any other major respects.

Often nations and groups within nations are superior to others in their standards of living. But such superiority is not due to a fundamental superiority of chromosomes and genes. Hence it is due not to heredity, but to environment. In addition to factors already mentioned, environment includes climate, natural resources (metals, fuels, forests, etc.), soil fertility, and geographic location.

HOW THE POPULATION MAY BE IMPROVED · [E]Nothing can be done about the heredity of the people now living. Their chromosomes and genes were determined before they were born. We can work only to improve conditions that now exist and to make possible better future generations.

Much can be done to bring about improvement. No doubt you can think of items in addition to these: providing everybody with proper nutrition, getting rid of slums and other unfavorable conditions of the environment, making certain that people can get the medical care that they need, providing schooling for people of all ages who may want to study, making churches and other social agencies conveniently available to all, and providing recreational facilities for everybody.

The hopelessly defective people, who can never take their places as self-supporting citizens, must be cared for. They should be put into institutions where they will receive the best of care, and where they can live

[1]Page 53.

To which of the primary stocks do you think each of these persons belongs?

happily and as usefully as their limited abilities will permit.

It is every person's responsibility to find out the history of his own family in order to be sure about whether or not his family stock has some defect that might be passed on to any children he might have. Also, it is his responsibility to make sure that the family into which he marries is without such defect. There is no satisfaction greater than the knowledge that one's children possess a good heredity.

Checking What You Know

BIOLOGICAL FACTS · (*Do not write in this book.*) **Pages 465–475. 1.** Name at least four types of fossils.

2. Dinosaurs were ancient (1) invertebrates; (2) fishes; (3) amphibians; (4) birds; (5) mammals.

3. Variations in living things occur from generation to generation, the more marked ones being known as __?__.

4. What are the five factors that are important in bringing about changes in living things?

Pages 475–489. 5. Several of the earliest discoveries of the laws of heredity were made by __?__.

6. A guinea pig known to be of a pure black strain is crossed with one known to be of a pure white strain. All the offspring (F_1) are black. Hence black in guinea pigs is *recessive* in relation to white.

7. In such a crossing as that indicated in No. 6, the recessive character is *lost*. It *will not* appear in a later generation.

8. In body cells there are *two* sets of chromosomes, and hence there is a pair of *chromosomes* for each hereditary character. In sex cells there is only one set of chromosomes, and hence there is one *chromosome* for each character.

9. When certain breeds of "red" cows are crossed with white, the calves are neither red nor white, but have an in-between shade. This is an example of __?__ dominance.

10. Genes for sex-linked characters are present in the *Y* chromosome.

11. When Rh + and Rh − blood are brought together in the blood stream, the *white* corpuscles from one of the two sources will be destroyed.

12. Some *chemicals* may be used to bring about mutations in plants.

13. Mutations appear most frequently in organisms reproducing *asexually.*

Pages 489–504. 14. The three methods of plant-breeding are __?__, inbreeding, and hybridization.

15. Inbreeding is *more* likely to produce pure strains than is hybridization because it brings together the genes of the same or closely related individuals.

16. Hybridization is more likely than *inbreeding* to produce variations in the offspring because hybridization combines *similar* sets of chromosomes and genes.

17. What are four kinds of characteristics sought for in the development of superior kinds of living things?

18. The plants grown from the seed of a highly desirable hybrid plant are *very likely* to have the desirable qualities of the parent plant.

19. Human genetics follows *different* laws *from* those that govern plant and animal genetics.

20. People of different racial stocks all belong to *the same* species.

21. *Some* races of human beings are known to be biologically superior to others.

BIOLOGICAL PRINCIPLES · **1.** In nature, only the fittest survive.

2. The kinds of plants and animals that inhabit the earth change in form over long periods of time.

3. The changes in organisms from generation to generation may be slight or great.

4. Individuals die, but life continues from age to age.

5. Many kinds of living things survive for a while, then lose in the struggle for survival and disappear from the earth.

6. Some changes in living things make them better able to survive, while others bring about their disappearance from the earth.

7. All the kinds of organisms now living are only a small part of the total number of kinds that have lived on the earth.

8. Plant and animal characters are inherited according to definite laws.

9. Energy and matter can be neither created nor destroyed, but they are passed on from organism to organism in endless succession.

10. Every living thing is the product of two inseparable factors, heredity and environment.

11. Acquired characters are not inherited.

12. Heredity provides the native capacities of a plant or an animal, and environment determines to a great extent how fully these capacities will be developed.

BIOLOGICAL TERMS

**embryo **heredity

Applying and Extending What You Know

AS SCIENTISTS WORK AND THINK · 1. Read again pages 475–482, dealing with Mendel's experiments. Which scientific attitudes are shown in the account of Mendel's work? Which of the elements of scientific method are indicated?

2. Formerly even some biologists believed

The children of a skillful player will not inherit his *skill* in playing, though they are likely to inherit his *capacity* for playing well. Can you explain why each generation must start its education and training from the beginning?

Press Association

that acquired characters could be inherited. Perhaps the most famous of them was the French zoologist Lamarck. In support of his belief he invented the following hypothesis to account for giraffes' having such long necks. Centuries ago giraffes began stretching their necks to get higher leaves to eat. As a result, their necks became a little longer during their life-times. Some, at least, of this added length was inherited by the giraffes' offspring. Consequently these young giraffes started life with slightly longer necks than their parents had had at birth. After many generations, therefore, many small lengths, added together, resulted in a neck several feet long, such as giraffes now have.

Weismann,[1] a German biologist, challenged this belief. He did so after performing the following experiment: He selected a pair of mice and measured their tails accurately. He then cut off their tails. He also cut off the tails of all their offspring for twenty generations. At the end of that time he measured the tails of the twentieth generation, and found that their tails were just as long as those of the first generation. Can you identify the elements of scientific method used in this investigation?

3. In 1865 Mendel presented the results of his research on pea plants before the Brünn Society of Natural History. To his intense disappointment, for he realized the significance of his results, nobody present displayed interest in his report. It was later published in the local scientific journal, but this journal had limited circulation and no prominence. Hence Mendel's research remained unnoticed until about fifteen years after his death.

By 1900, however, each of three noted biologists, a German (Correns), a Hollander (De Vries), and an Austrian (Tschermak[2]), had come across the published paper. Impressed with its importance, they performed with plants experiments similar to those done by Mendel and secured the same results that Mendel had secured. Within another two years, other scientists carried out experiments of the same kind with animals. Their results were the same as those secured by the four scientists who had experimented with plants. The great honors that should have come to Mendel at least a third of a century earlier were then given him posthumously (after his death).

What scientific attitudes are related to this account?

APPLYING YOUR KNOWLEDGE OF BIOLOGY · **1.** Are fossils being formed on the earth today? If you think so, where are they being formed? What kinds of living things are likely to be preserved in fossil form?

2. A popular comic strip often shows ancient men riding on the backs of dinosaurs. What is incorrect about this?

3. A woman in California owns a two-headed snapping turtle. The heads fight over food so fiercely that when they are being fed, a piece of cardboard has to be placed between them, to prevent the one that does not happen to have a mouthful of food from attacking the one that has. This animal, Ditmars's snake,[3] and other such animals are really "Siamese twins," that is, twins that are not completely separated. Do you think such animals are freaks or mutants? Why?

4. How would you explain this old saying: "A wooden head is inherited, but not a wooden leg"? To which of the principles on pages 505–506 is this saying most closely related?

5. Farmers prefer purebred live-stock to hybrids, but they often prefer hybrid corn to corn from a pure strain. Explain.

6. Identical twins develop from a single egg. Why are they so much alike? Why are they always of the same sex?

7. Fraternal twins are those which develop from two separate eggs fertilized by two different sperms. They are usually no more alike than other brothers or sisters. Why? Why are they sometimes of the same sex, and sometimes not?

TOPICS FOR INDIVIDUAL STUDY · **1.** In a textbook of historical geology or in an encyclo-

[1] *Weismann* (vīs'män); lived, 1834–1914.
[2] *Tschermak* (chĕr'mäk); lived, 1871–?
[3] Page 472.

Wide World

Until fairly recent times any European who wished to do so might come to the United States or Canada to live. Now only limited numbers (quotas) from other countries are allowed to seek residence each year and only those who can pass thorough medical and mental examinations. Other factors are also considered. What reasons can you state for or against restricting immigration? Is there any relation between immigration and improvement of the population? Explain

pedia, look up the Mesozoic era (the Age of Dinosaurs). Find out what kinds of dinosaurs existed then; how large they were; where they lived; what they ate; whether they laid eggs or were born alive; why they became extinct. Take notes on your reading as a basis for a report to your class.

2. Make a similar study of the Coal Age.[1]

3. Obtain a seed catalogue such as is used by gardeners and farmers for ordering seeds. Go through it carefully to learn about the various kinds of hybrid plants which are available. Note what claims are made for the superiority of the hybrid plants.

EXPERIMENTS · 1. How is the development of young corn plants affected by albinism (illustration, p. 488). From a biological supply house obtain a hundred or more seeds of field corn. Specify in your order that you wish seed that contains the gene for albino corn. Plant the seed in any convenient container. When the seeds sprout, count the number of green seedlings

[1]Page 560.

and the number of white seedlings. What is the ratio? From this ratio, what do you infer about the genes of the albino seedlings? of the green seedlings? Take care of the seedlings so that they may continue to grow. From your observations can you answer the question with which this experiment begins?

BIOLOGY OUT OF DOORS · **Making a collection of fossils.** If you live in an area where there is sandstone, limestone, or shale rock, look for fossils such as the shells of mollusks,[1] coelenterates[2] (corals), and other ancient sea animals, and such as mastodon or shark teeth. You may find prints of leaves and other plants on the surface of pieces of soft coal. The whole class may find enough specimens to start a "fossil museum," which may be enlarged by classes in following years.

COMMUNITY APPLICATIONS OF BIOLOGY · **1. Studying science from exhibits.** If there is a museum of natural history near your school, visit it to study the displays of fossils that you will find there. Take careful notes as a basis for future reports.

2. Learning about new achievements in plant and animal breeding. Make arrangements to visit an agriculture experiment station if there is one near enough to your school. Try to arrange in advance to have one of the workers at the station show and explain to the class the work which is being done on the development of new kinds of plants or animals.

[1]Page 524. [2]Page 517.

PANEL DISCUSSIONS[3] · 1. *Topic:* The work of Mendel has proved of greater value to the world than that of Edison.

2. *Topic:* Practical ways in which the environment of all the people in our community may be improved.

3. *Topic:* Immigration into this country—as it is and as it should be.

4. *Topic:* The relative values to the world of the progress made in plant and animal breeding.

BIOLOGY IN THE NEWS · Watch the newspapers and magazines for accounts of various kinds of new or unusual plants and animals. Post those most suitable on the bulletin board. Make a special note of those that would be most suitable for discussion in class or in the science club.

BOOKS FOR REFERENCE

BOYLE, MARY E. *Man before History.* Little, Brown and Company.

COULTER, J. M. *Evolution, Heredity, and Genetics.* Public School Publishing Company.

FENTON, C. L. *Life Long Ago.* The John Day Company.

SCHEINFELD, AMRAM. *You and Heredity.* Frederick A. Stokes Company.

BOOKS FOR LEISURE READING

DE SCHWEINITZ, KARL. *Growing Up.* The Macmillan Company.

LUCAS, JANNETTE M. *Man's First Million Years.* Harcourt, Brace and Company.

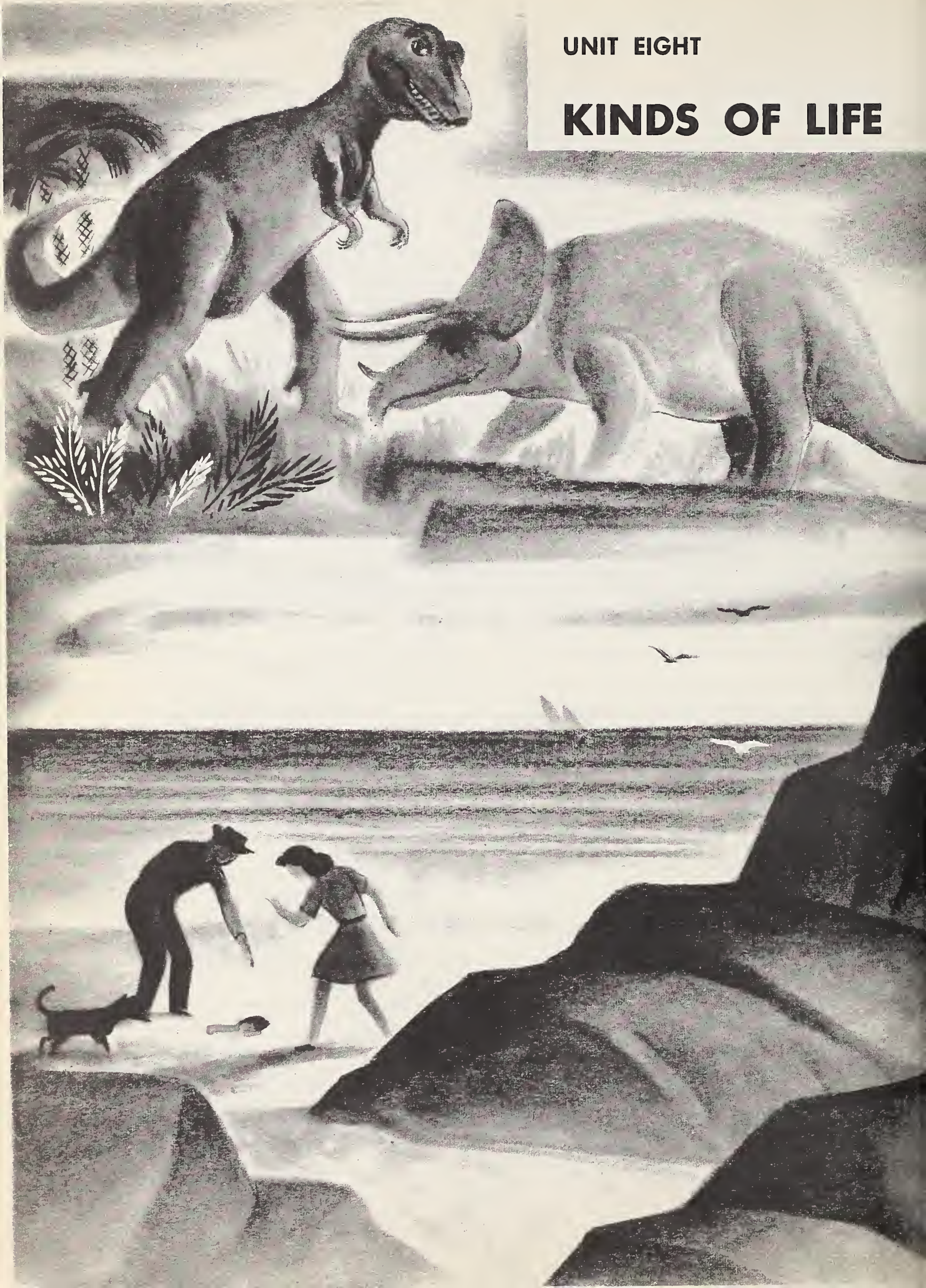
OSBORN, H. F. *Men of the Old Stone Age.* Charles Scribner's Sons.

STRAIN, FRANCES B. *Being Born.* D. Appleton-Century Company, Inc.

[3]Page 116.

UNIT EIGHT

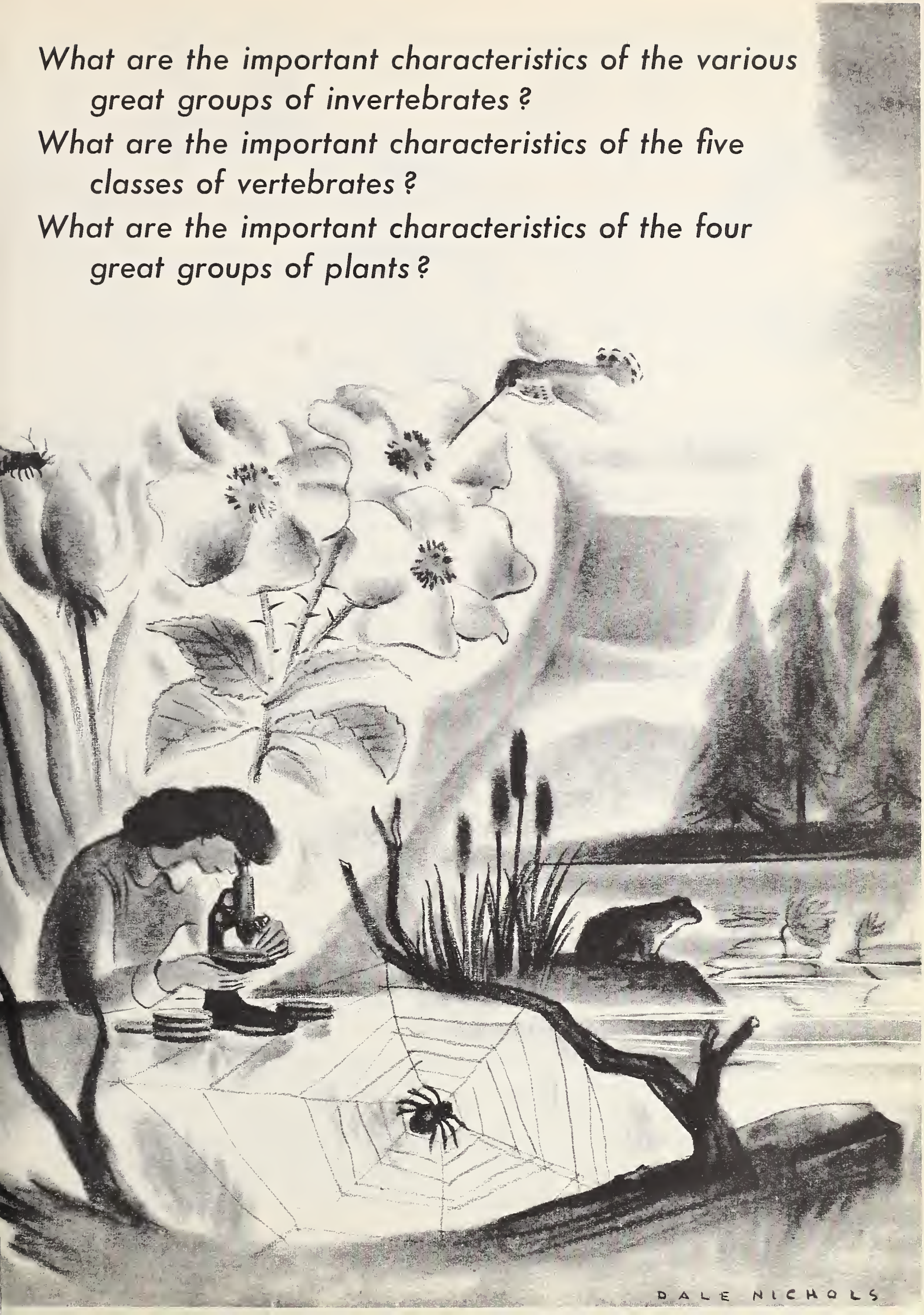
KINDS OF LIFE



What are the important characteristics of the various great groups of invertebrates?

What are the important characteristics of the five classes of vertebrates?

What are the important characteristics of the four great groups of plants?



One way of indicating how important groups of plants and animals are related · Different scientists would not agree upon all parts of such a diagram, because so much still remains to be discovered about the exact relationships of living things. Scientists would, however, agree that, in general, the nearer the bottom of this diagram an organism is, the simpler it is in structure and the longer it has probably been on the earth

18

THE INVERTEBRATES, OR ANIMALS WITHOUT BACKBONES

1. What Are Some Important Facts about the Animals with One-celled Bodies[1] ?

[E]The Protozoa are the lowest forms of animal life because they are the simplest in structure. They are the only animals each of which has a body consisting of only one cell. Scientists believe that these one-celled animals were the first animals that lived on the earth (illustration, p. 512.)

The fact that the Protozoa have lived so long on the earth is evidence that they are a successful group of animals[2] (illustration, p. 39). Other evidence is that they live in almost every part of the earth, and that there are more individual animals among the Protozoa than there are in the different kinds of the Metazoa**[3] combined. There are, however, fewer species of these animals than there are species in some of the other animal phyla (illustration, p. 514).

To the Teacher. These materials on classification either may be studied as a part of the regular course or may be omitted entirely from regular study and used solely for reference. Footnote references to these materials have been placed wherever needed throughout the rest of the book.

WHERE THE PROTOZOA ARE FOUND · Billions of protozoans live in the oceans. Billions more are in fresh-water streams, lakes, and ponds. Still other billions exist in moist soil to a depth of several inches. Some protozoans can keep alive for a considerable length of time, even though their habitats dry up. But all protozoans are aquatic animals, that is, they can live only in water or in blood, milk, or some other liquid which is mostly water (illustration, p. 39.)[4]

The protozoans that inhabit water and soil are free-living animals. A free-living animal is one that captures prey or eats plant and animal materials that it finds, but it does not live upon or inside the body of any other living organism. Countless protozoans, however, are not free-living organisms. These live inside the bodies of all larger animals, and even, in some cases, inside other protozoans.

Some of these one-celled inhabitants of other animals do their hosts neither harm nor good, though they themselves benefit. This

[1]The scientific name of this phylum is *Protozoa* (prō tō zō'*ȧ*). [2]Pages 43–44.

[3]*Metazoa* (mĕt *ȧ* zō'*ȧ*) is the name of the group that includes all the animals except the Protozoa. The Metazoa, or *metazoans* (mĕt *ȧ* zō'ănz), are therefore the animals whose bodies are made up of a great number of cells of many different kinds.

[4]No attempt is made in this drawing or in any of the drawings representing groups of plants or animals, in this unit, to indicate true or relative sizes. In some of these drawings, moreover, species are grouped together that would seldom or never actually be found in the same habitat.

The approximate numbers of species that make up the various animal and plant phyla · Each unit represents 3000 species. There is not space enough here to represent the species of the arthropods and the seed-bearing plants, of which there are respectively about 675,000 and 200,000 species. Can you invent another kind of drawing to represent these facts? If so, make one for a bulletin-board display

kind of partnership is an example of commensalism.*[1] Other protozoans are parasites. Some of these latter live in the human blood stream, tissues, or intestines or other organs. They are the germs of diseases that kill hundreds of thousands of people every year. Other parasitic protozoans injure men indirectly by causing diseases among his cattle and other domestic animals.

COLONIAL PROTOZOANS · Not all protozoans exist singly, as amebas and paramecia do. Some are colonial forms, so called because they live attached to one another in groups, or colonies (illustration, p. 516).

The cells that compose a simple colony are individual protozoans of the same kind. They are all alike and carry on their life activities practically as if each lived by itself. There are, however, colonial organisms in which the cells are not all of the same kinds and which are not all independent of one another. *Volvox*, one of the commonest of these, will be described later.

PROTOZOA AND MAN · Most protozoans have no effect upon man's welfare. Man is gaining success in his efforts to control the protozoans whose life activities interfere with his welfare. He is constantly learning more effective ways of preventing and curing diseases caused by protozoan parasites. Some of these ways are discussed in another part of this book.[4]

2. What Are Some Important Facts about the Animals with Porous Bodies, Namely, the Sponges[2] ?

If you were to go into a pet store and ask to buy a dog, you would be surprised if the clerk brought you the skeleton of a dog. Yet when you ask to buy a sponge, the clerk brings you the skeleton of a sponge animal, and that is what you want.

The sponges that we buy are the endoskeletons**[3] of animals that live attached to the ocean bottom. From the time of ancient Greece, people living on the shores of the Mediterranean Sea have used sponges for various household purposes. Until a little more than a hundred years ago everybody, even the biologists, thought that sponge animals were plants.

All sponges are aquatic animals and all are free-living. The young, or larvae, do not resemble the adults. They swim about actively for a while before they attach themselves to some object and complete their development.

The most familiar kinds of sponges are marine animals. They inhabit the warm, shallow water along the coasts of Florida, Cuba, and the Mediterranean Sea. They are found also in other parts of the world. Venus's-flower-basket and a few others are deep-sea animals.

About twenty-five species are fresh-water forms. These grow on rocks, sticks, and logs in the streams, lakes, and ponds of the United States and Canada.

[1]*Commensalism* (kŏ mĕn′săl ĭzm).

[2]The scientific name of this phylum is *Porifera* (pō rĭf′ẽr *ȧ*).

[3]*Endoskeleton* (ĕn dō skĕl′ē tŭn): the framework, or supporting structures, *inside* an animal's body. Bones are parts of endoskeletons.

[4]Pages 280–281.

Colonial protozoans · State at least one respect in which colonial protozoans are similar to metazoans and at least one respect in which they are different

CHARACTERISTICS OF SPONGES · Sponges are the lowest and simplest of all the Metazoa. They are more simple in structure than any other many-celled animals, except *Volvox* and other colonial animals.[1]

Though different kinds of sponges differ greatly in appearance, nevertheless all are alike in general structure: (1) Their bodies always consist of two layers. Between these layers is a jelly-like substance. (2) Their bodies are porous; that is, millions of canals, or pores, extend in all directions through them. Many of these pores are microscopic. Water passes into the interior of the sponge through all the pores, and, in many species, flows out through one large opening in the end of the sponge (illustration, p. 518).

DIVISION OF LABOR[2] · Sponges are made up of several kinds of cells, each performing special functions. Some have flagella. These beat in a certain way that causes currents to flow continuously through the pores of the sponge and thus brings oxygen in the water to all the cells. Also, these cells secure food that all the cells use, by engulfing, or taking in, minute organisms and bits of organic material.

Some cells are reproductive cells, or those that produce the young sponges. Others act like muscle cells, and make the pore openings

[1]Pages 564–566.

[2]Page 43.

smaller when there are irritating substances in the water.

In the jelly-like material between the two layers of a sponge's body are ameboid cells, that is, cells that look, move, and act like amebas.[1] These aid in distributing the food obtained by the food-getting cells of the inside layer. They function also in getting rid of waste materials, not only their own, but also those produced by other cells. Some of them take from the sea water certain materials and out of these materials make the sponge skeleton. Ameboid cells similar to those in sponges exist in all the higher metazoans, including man.

SPONGES AND MAN · Sponges are of relatively little importance to man. The endoskeletons of a few kinds have some uses in industry, as well as in the home.

3. What Are Some Important Facts about the Animals with Bag-like Bodies[2]?

During the Second World War the armed forces of the United Nations captured from the Japanese the Marshall Islands and other groups of islands in the Pacific Ocean. Each of these groups is made up of a large number of low, irregular, ring-shaped islands called *atolls*.[3] An atoll is composed of the shells, or partial body-coverings, of billions of tiny coral animals. Each generation builds upon the shells of the preceding generation. After many centuries the walls of the atoll reach the surface of the ocean, in places even where the depth is greater than a hundred feet.

Coral reefs and islands are found in many parts of the world. The Great Barrier Reef of Australia was made by coral animals. The Florida Keys, the Bermudas, the Bahamas, and many other islands are likewise coral formations.

CHARACTERISTICS OF COELENTERATES · The coral animal is a coelenterate. Like the sponges, all coelenterates are free-living. Some live singly and others in colonies. Many kinds are free-swimming (the medusae) (illustration, p. 443). Others are attached to rocks or other objects (the polyps[4]). All coelenterates are aquatic, and most of them live in the oceans. If you have visited an ocean beach, you have probably seen coelenterates that look like strange flowers growing on the rocks. These are sea anemones.[5] You may also have seen jellyfish swimming in the water or lying dead on the beach.

One fresh-water coelenterate, *Hydra*, can be readily obtained for study from streams and ponds in many parts of North America. It looks like a piece of brown or green thread about half an inch long, with from six to ten smaller threads attached to one end (illustration, p. 431). The sea anemones, jellyfish, and hydras have no protective coverings, such as the corals and some other coelenterates have.

Coelenterates are of many brilliant colors. Also, they vary greatly in size. The individuals of some of the colonial forms are mere

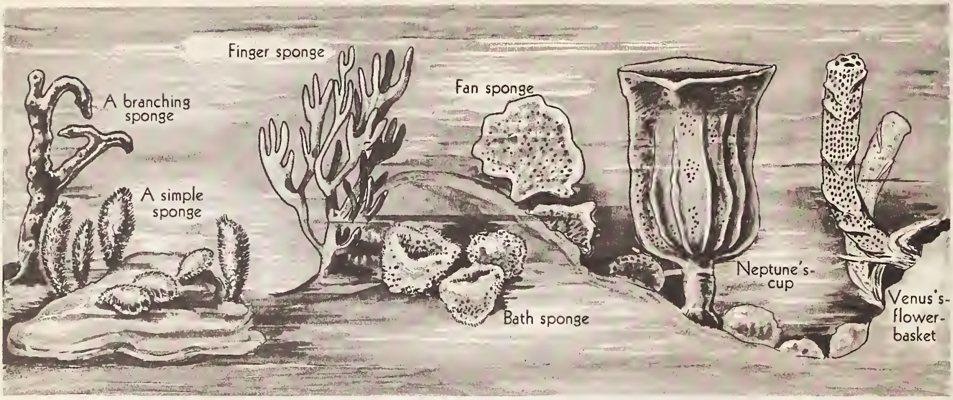
[1]Page 47.

[2]The scientific name of this phylum is *Coelenterata* (sē lĕn tĕr ā'tȧ). These animals are commonly called *coelenterates* (sē lĕn'tĕr āts).

[3]*Atoll* (ăt'ŏl).

[4]*Polyp* (pŏl'ĭp).

[5]*Anemone* (ȧ nĕm'ō nē).

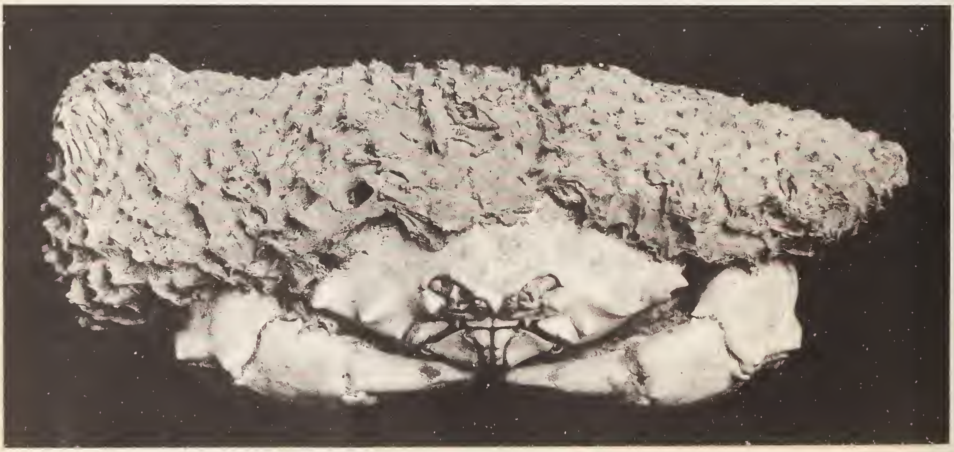


Sponges vary in size from that of a pin-head to about eight feet in diameter. Some kinds are masses of tissue without definite shapes. Others have characteristic forms. Sponges are of many colors—white, gray, black, purple, blue-green, yellow, orange, brown, or red. Why do you think sponges were formerly thought to be plants?[1]

[1]Pages 45–47.

The crab placed a piece of sponge on its back. The sponge became attached to the crab's shell, and as the sponge grew the crab became better concealed from its enemies. By being carried about the sponge was better able to secure food. This sort of partnership is an example of symbiosis. Explain. (See the Glossary and the Index)

American Museum of Natural History



specks. In contrast, a jellyfish twelve feet in diameter with tentacles*[1] more than a hundred feet long has been reported.

BODY STRUCTURES · Every coelenterate has a body that roughly resembles a bag. It is composed of two layers of cells, with a thin layer of jelly-like material between. If it were cut across in any direction from one edge to the other through the center, the two halves would be similar (illustration, p. 520).[2]

A coelenterate has only one opening, or mouth, which is surrounded by tentacles. The animal takes in food and also gets rid of waste materials through its mouth. The mouth opens into a central cavity. In sponges all the food is digested in certain cells. In coelenterates the food is mostly digested in the cavity, which is therefore a primitive*[3] digestive organ.

COELENTERATES AND MAN · The life habits of coelenterates have relatively little effect upon those of man. The reefs built by corals, however, are of great importance in navigation.

4. What Are Some Important Facts about the Three Phyla of Worms — the Flatworms, the Roundworms, and the Segmented Worms?

The illustration on page 56 shows several animals that look like worms, but are not. There are only three phyla of animals that are true worms, and not all of these animals look as we should expect a worm to look. These three phyla are the flatworms, the roundworms, and the segmented worms (illustration, p. 521). They will be briefly described here one after the other, though most biologists place the spiny-skinned animals (the echinoderms), which are here discussed later, between the roundworms and the segmented worms (illustration, p. 521). They do so because the segmented worms are in general more complex in structure than the "spiny-skins."

CHARACTERISTICS OF THE WORMS · **1. The flatworm.**[4] Many flatworms are free-living forms. These are found chiefly in fresh water or in the ocean, though some live in moist soil. The rest live upon or inside the bodies of many kinds of other animals. Most of these are parasites, some of which use man as their host.[5] Others are commensals. An example of the latter is a species that lives attached to the gills of the king crab. It profits by having shelter and by being able to get what food it needs from particles of the crab's food. Its host, the crab, neither gains nor loses from this association.

Flatworms have soft, flat bodies, without skeletons of any sort. Their bodies are made up of three layers of cells—instead of two, as

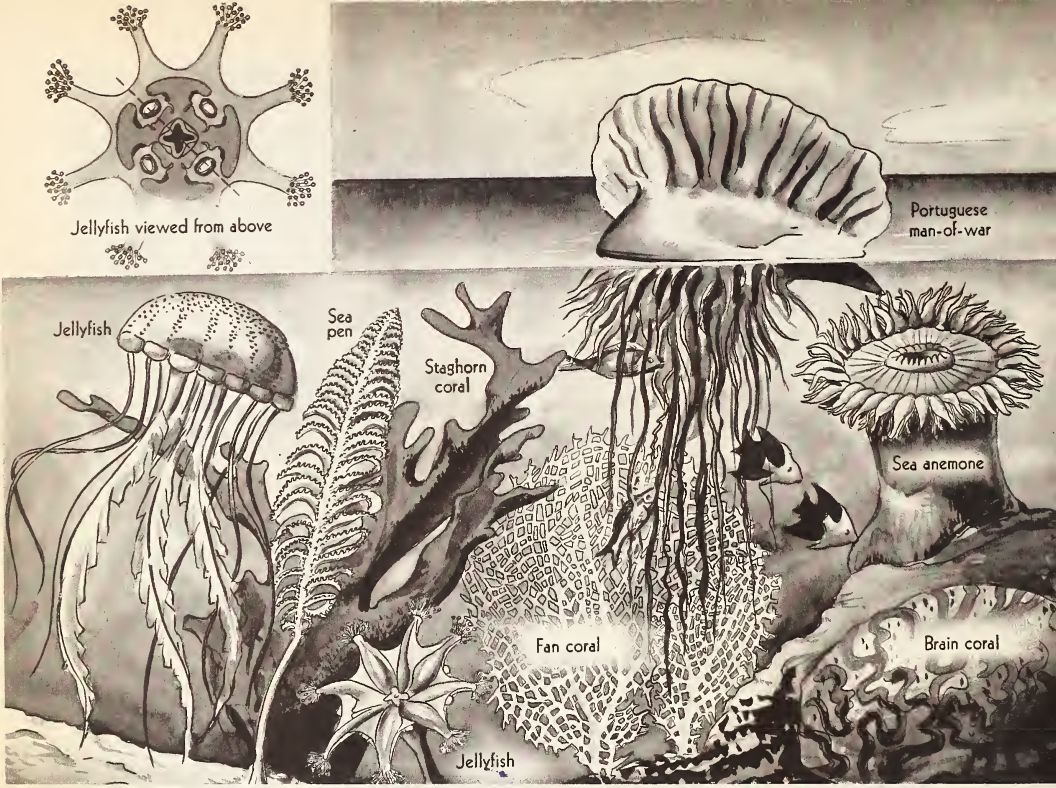
[1]*Tentacle* (tĕn'tȧ kl). Tentacles are slender, flexible structures used by coelenterates and some other animals in moving about, in securing food, and in performing other functions.

[2]Biologists call this plan of body structure *radial symmetry.*

[3]*Primitive* (prĭm'ĭ tĭv): having to do with the early, or beginning, stages of development.

[4]The scientific name of this phylum is *Platyhelminthes* (plăt ĭ hĕl mĭn'thēz).

[5]Pages 281–285.

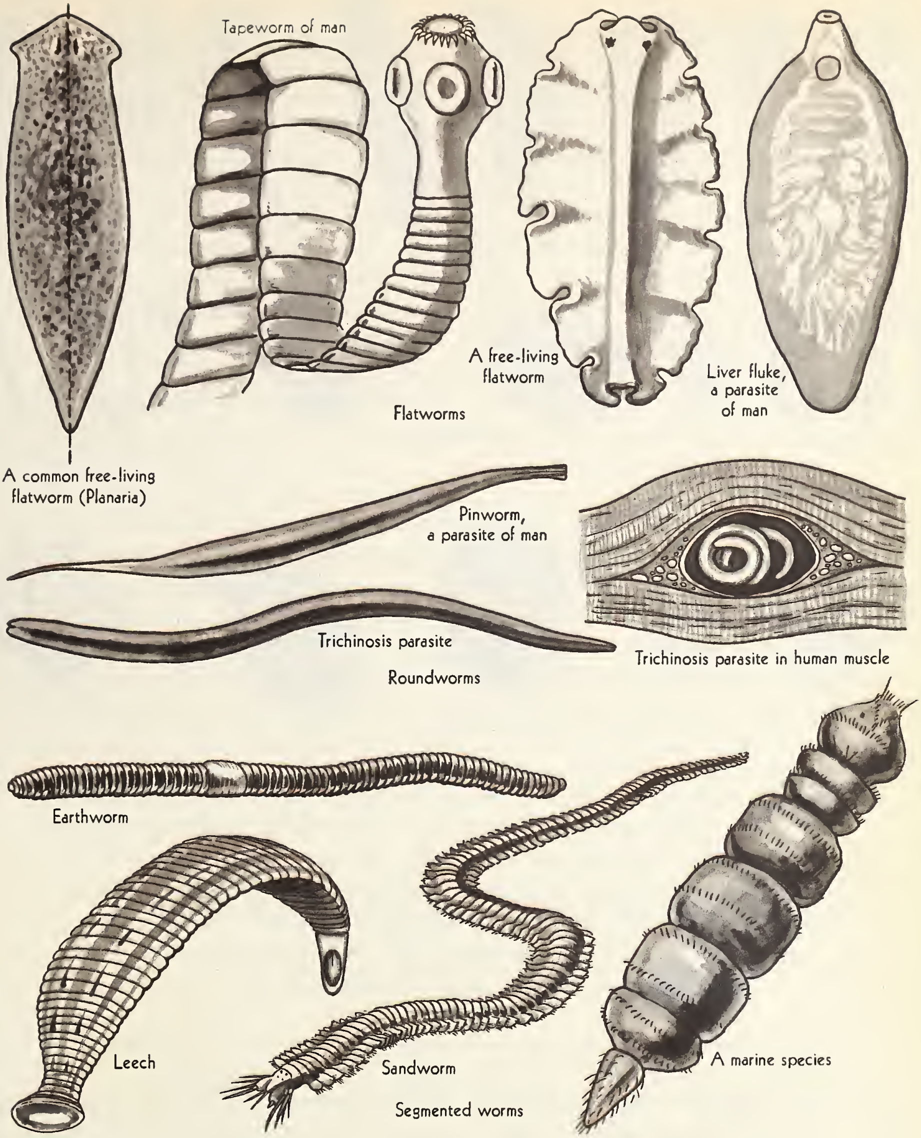


Coelenterates · Coelenterates have all the types of cells that sponges have, and, in addition, they have nerve cells. Practically all coelenterates have, also, stinging cells, which function as a defense against enemies and in capturing prey. Also, coelenterates have well-developed tissues. Do you infer from these facts that there is greater or less division of labor in coelenterates than in sponges? Justify your answer

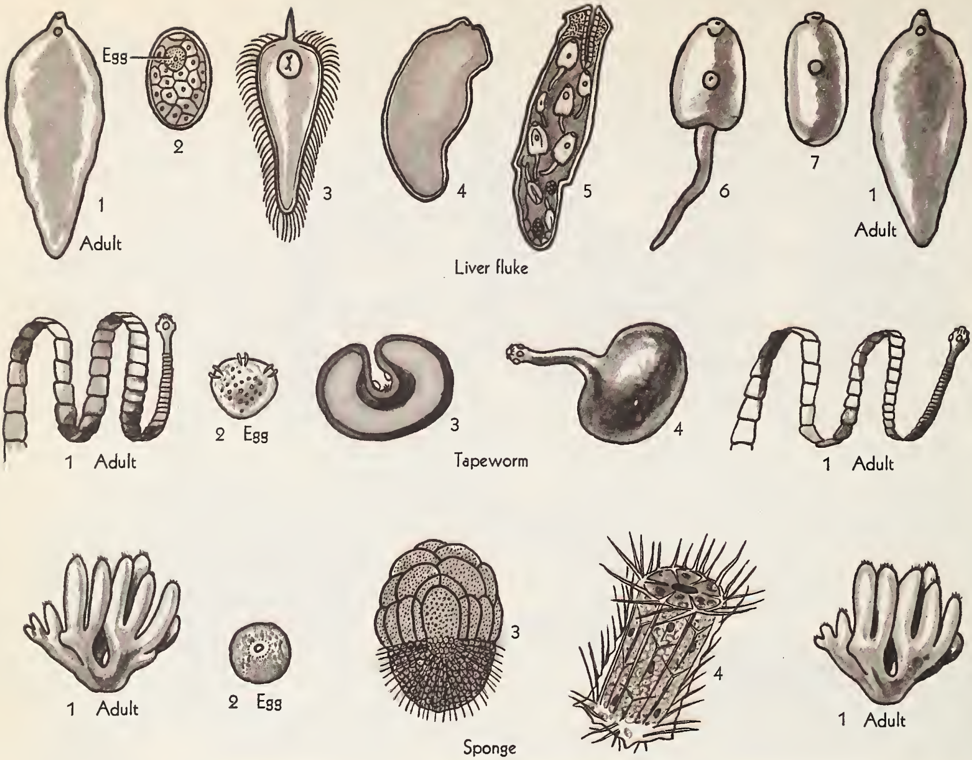
are the bodies of sponges and coelenterates. Cutting the body of any flatworm lengthwise through the middle would divide it into similar right and left halves. In this respect a flatworm's body is like ours and, in fact, like the bodies of most kinds of animals (illustration, p. 521)[1]. Some kinds of flatworms can crawl, and that is something that no simpler metazoan, that is, no sponge or coelenterate, can do (illustration, p. 521).

Unlike sponges and coelenterates, flatworms are high enough in the scale of life to have some simple systems of organs. Thus, because there is a wider variety of structures in flatworms than in sponges and coelenterates, there is likewise a more extensive division of labor.

[1]Biologists call this plan of body structure *bilateral symmetry*.



Representatives of the three phyla of worms · The drawing of Planaria shows bilateral symmetry. **Topic for Individual Study:** Vinegar eels. Look up *nematodes* in a college biology textbook



Many kinds of animals, when hatched from the egg, do not look at all like their parents. The series of changes in form that an animal goes through in developing into an adult is known as a metamorphosis. The metamorphoses of insects are discussed on page 182. **Topic for Individual Study:** The metamorphosis of some invertebrate. Among the invertebrates, complete metamorphoses, such as those pictured here, are much more common than incomplete, or gradual, metamorphoses (illustration, p. 181)

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2. **The roundworms.**[1] Roundworms are slender animals, with smooth, soft bodies without skeletons, which taper somewhat toward one or both ends. They range in size from a mere speck to three or more feet in length. Many kinds are free-living. These are found in enormous numbers all over the world in fresh-water lakes, streams, and ponds, in the ocean, and in moist soil. A million roundworms (nematodes[2]) may exist in a single spadeful of garden soil. Many species are parasites of various kinds of plants and animals, including man (illustration, p. 521).[3]

[1]The scientific name of this phylum is *Nemathelminthes* (nĕm ȧ thĕl mĭn′thēz).

[2]*Nematode* (nĕm′ȧ tōd).

[3]Pages 281–285.

3. **The segmented worms,[1] the highest worms.** All the worms in this phylum have long, round, soft bodies without skeletons, but, unlike the roundworms and the flatworms, these worms are segmented. A segmented animal is one that has a body made up of segments.**[2] Segments are distinct sections, or divisions. The body of an earthworm, for example, is made up of more than a hundred segments, which are somewhat like flat rings.

Some annelids live in the ocean (illustration, p. 521), others in fresh water. Other species burrow in moist soil or in the moist sand or mud of the seashore.

Most annelids are free-living animals. A few are true parasites. Others—for example, various species of leeches—are partial parasites. Different ones of these last ("bloodsuckers") attach themselves to fish, turtles, and frogs, and even to higher animals, including man. After they have filled themselves with blood, they drop off. They are called partial parasites because they do not remain on their hosts all the time. The "medical leech" can expand enough so that it can suck in three times its own weight of blood. This is enough food to last it for nine months.

The segmented worms are much more complex in structure than the animals of any of the groups previously studied. Therefore they have a much wider division of labor. They have well-developed digestive and nervous systems. Among the animals of this phylum, moreover, are the simplest animals that are truly terrestrial animals. The animals belonging to the groups previously studied are really aquatic. Even those that are found in soil actually live in the water that the soil contains.

WORMS AND MAN · The flatworms and the roundworms are of great importance to man because of the serious diseases which parasitic members of these two phyla cause in people and in domestic plants and animals. The annelids, however, have relatively little effect upon man's survival. An exception is the earthworm, whose life habits make it of great value to agriculture (illustration, p. 521).

5. What Are Some Important Facts about the Spiny-skinned Animals[3] ?

If you have ever visited an ocean beach, you have probably seen brown and purple starfish clinging to rocks or crawling slowly over the rocks and sand in shallow water. In spite of their name, starfish are not fish. They belong to the numerous group of animals with rough, bony, or leathery exteriors which, in most species, are covered with spines. All are marine forms. All are free-living. Most "spiny-skins" can move about slowly, and a few can swim. The sea lilies (crinoids) remain fixed to the bottom in the deep ocean.

[1]The scientific name of this phylum is *Annelida* (ă nĕl′ĭ dȧ). These animals are commonly called *annelids* (ăn′ĕl ĭdz). [2]*Segment* (sĕg′mĕnt).

[3]The scientific name of this phylum is *Echinodermata* (ē kī nō dûr′mȧ tȧ), which comes from two Greek words meaning "spiny" and "skin." These animals are commonly called *echinoderms* (ē kī′nō-dûrmz).

CHARACTERISTICS OF THE "SPINY-SKINS" · The starfish and their relatives have bodies made, usually, of five similar parts grouped around the mouth. The adults do not have right and left halves, as do the worms and higher animals. Instead, if one of them were cut across in any direction from one edge to the other through the center, the two halves would be similar (illustration, p. 525).[1] In this respect they are like the coelenterates.

ECHINODERMS AND MAN · On the whole, the animals of this phylum are of little importance to man. The life habits of most of them do not affect man's welfare in any way.

6. *What Are Some Important Facts about the Mollusks[2]?*

In earlier times stories about "sea monsters" were fairly common. Some of these tales were probably started by sailors who had seen giant squids. It is not surprising that such stories were told, because the giant squid might well be considered a monster, both in appearance and in size.

During the early part of the nineteenth century a steamship in the Atlantic Ocean came upon a giant squid on the ocean surface. Its body was about fifty feet long, not counting the ten long arms (tentacles), and it was about twenty feet around at the largest part.

The captain decided to capture the animal for scientific study. First, members of the crew tried to kill it by shooting it. They fired many shots through it, but these appeared to have little effect. Finally they managed to stick a harpoon into the jelly-like body and to wind the rope attached to the harpoon around the body. But when they tried to hoist the squid onto the deck, the rope cut its body in two. The part with the head and tentacles dropped back into the water and swam off. The rest was lifted to the deck. It was, however, only a small portion, weighing about forty pounds, and of little value for scientific study.

CHARACTERISTICS OF THE MOLLUSKS · The giant squid is a mollusk. Not only is it the largest mollusk, but it is the largest of all the invertebrates. Common mollusks which you may have eaten include shell-fish, such as oysters, clams, scallops, and, if you have been in California, abalone "steaks." Shell-fish are not fish. They are not even closely related to fish.

Some aquatic species of mollusks, such as the squids and many kinds of clams and snails, are marine animals. Such others as fresh-water clams, or mussels, and snails live in the lakes and streams of many parts of the earth. Many kinds of mollusks—for example, the snails and slugs which are common in forests and gardens—are terrestrial animals.

All mollusks have soft bodies, which, in most species, are protected wholly or in part by a shell. In fact, many of the most beautiful sea shells are the protective coverings of mollusks. The commonest types of mollusk shells are all in one piece, like those of snails and abalones, or are in two parts, like those of clams and oysters. Slugs and cuttlefish have small plates of shell inside their bodies, but

[1]Footnote 2, p. 519. [2]The scientific name of this phylum is *Mollusca* (mŏ lŭs′kȧ). These animals are commonly called *mollusks* (mŏl′ŭsks).

near the surface. One kind of mollusk (*Chiton*), which is found clinging to rocks in shallow ocean water, has a shell made up of eight plates. In contrast, an octopus has no shell whatever.

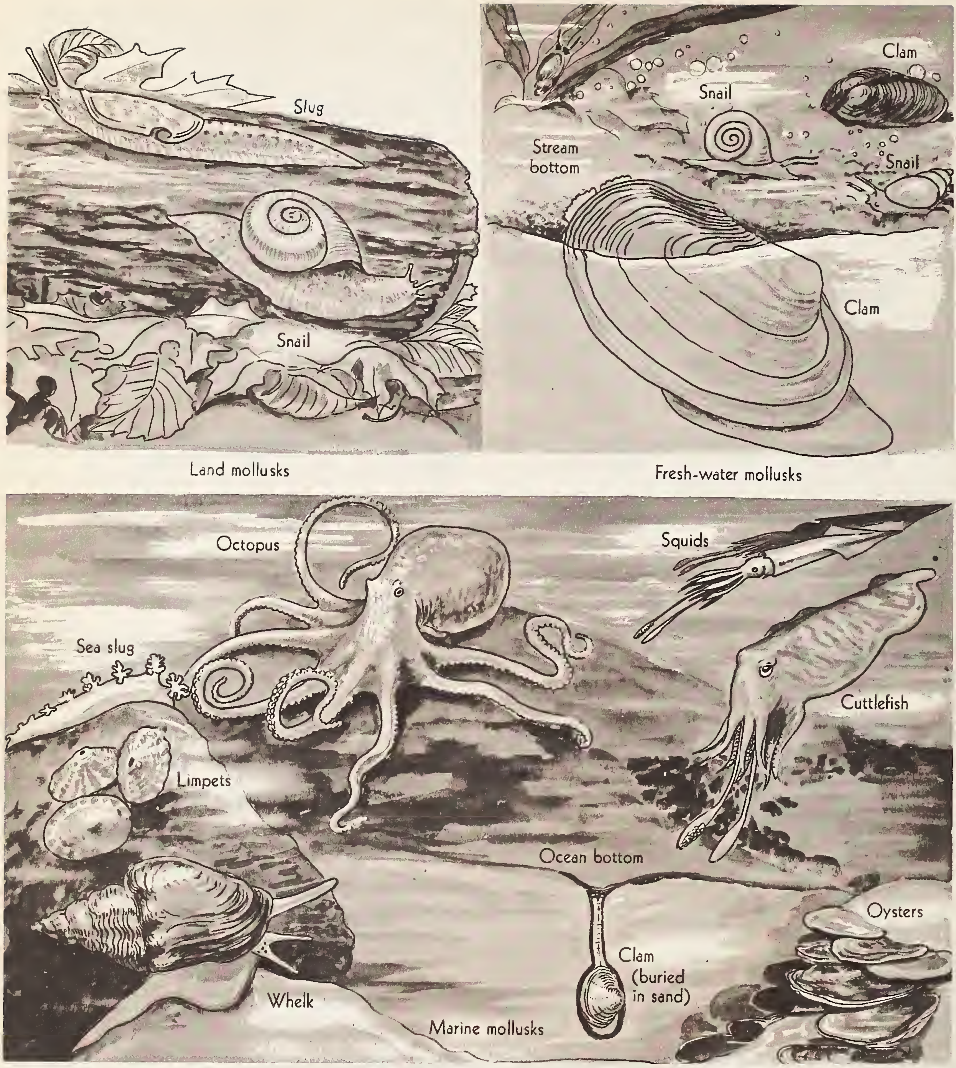
Most mollusks have bodies that could be divided into right and left halves, like the bodies of the worms and the higher animals, including man.[1] Every mollusk has also a foot, which is a modified structure adapted to fit the kind of life that the animal leads.[2] Thus the foot of the land snail is adapted to locomotion. That of the clam of the ocean tide flats is adapted to digging into the sand or mud. That of a free-swimming form, such as the squid, has become modified so that it consists of tentacles adapted to swimming and to seizing prey.

[1]Footnote, p. 520. [2]Page 23.

MOLLUSKS AND MAN · As has been indicated, people use many kinds of mollusks for food. Moreover, they eat enormous quantities of them. To ensure a constant supply of oysters, people have established oyster "farms" along both the Pacific and the Atlantic coast. On these "farms" they raise millions of dollars' worth of oysters every year.

The teredo, which is commonly called a "shipworm," is really a marine clam. Its

Spiny-skinned animals · What do you think are the advantages and the disadvantages of having such coverings as these animals have?



Mollusks · Adult mollusks are all free-living. Young mollusks (larvae) of some species are parasites. An example is the larva of the fresh-water clam, or mussel, from the shells of which pearl buttons are made. **Topic for Individual Study:** How the necessary annual supply of fifty-thousand tons of shells for pearl buttons from the Mississippi River and its tributaries is maintained

shell is modified in such a way that the animal can bore into wood. With this boring organ the animal does great damage to the bottoms of wooden ships, and sometimes so weakens the pilings which hold up wharves that the wharves fall into the water.

Octopuses have been known to attack divers, though such attacks are relatively rare. Divers in the Gulf of California, where large octopuses are numerous, frequently have these ugly creatures crawl over them. But if the men can control their fear sufficiently to remain motionless, the octopuses apparently do not know that the divers are alive and do not attack them. The men carry knives with which they defend themselves when necessary. They plunge the blade into the animal's body and give a sweeping cut, which usually kills the octopus.

Slugs are sometimes serious pests in gardens and greenhouses.

Many mollusks are of great value as scavengers. Important among these scavengers are fresh-water mussels. They purify water by eating microscopic particles of organic matter and minute living organisms.

7. What Are Some Important Facts about the Highest Invertebrates,[1] the Insects and Their Relatives[2]?

Scientists believe that the first terrestrial animal was an arthropod. This ancient arthropod was a scorpion (illustration, p. 553). It is believed to have lived at least three hundred million years ago. A hundred million years later, insects were numerous. Many of them were far larger than their descendants of today. For example, dragonflies with a two-foot wing-spread and cockroaches half a foot long thrived in the forests ages before there were any birds, flowers, or four-footed animals, such as inhabit the forests today. The illustration on pages 468 and 469 shows the ages in which scientists believe that the earliest arthropods existed on the earth.

More than three fourths of all the known kinds of animals now on the earth are arthropods (illustration, p. 514). Nearly 90 per cent of all arthropods are insects. The insects are probably the most successful[3] of all animals. Some biologists have said that, in the struggle between man and the insects for food, the insects may finally win and cause man to become extinct.

HABITATS · There are scarcely any parts of the earth's surface, except high mountaintops and the frozen areas near the poles, where arthropods are not found. Wingless insects were discovered by the first Byrd Expedition even on the Antarctic Continent. Some kinds of arthropods—for example, crabs, shrimps, and lobsters, and even a few kinds of insects—live in the oceans. Others, such as crayfish and many kinds of insects, inhabit fresh water. Still others, such as ticks, lice, fleas, and mites, are parasites on the bodies of man and other animals. The larvae of a few are parasites in animals, as are bot-flies in the stomachs of horses, cattle, and sheep.

[1]Some zoologists place the mollusks above the arthropods in the scale of life.

[2]The scientific name of this phylum is *Arthropoda** (är thrŏp′ō dȧ), and the animals are commonly called *arthropods* (är′thrō pŏdz).

[3]Page 43.

INSECT LIFE IN PONDS

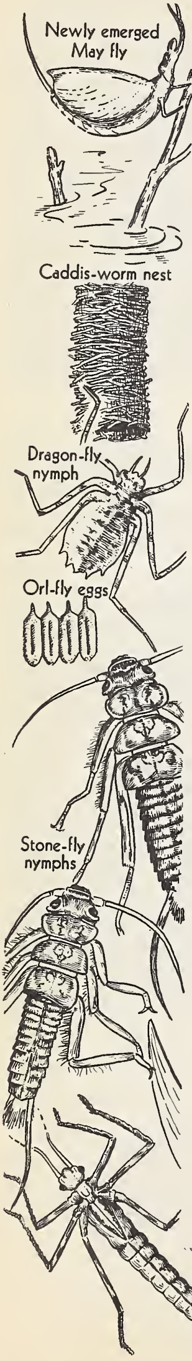
THE PONDS, swamps, lakes, or streams of your locality offer you opportunities for studying a great variety of insect life. Some forms are almost certain to be new to you. Among these are likely to be insects which, as larvae and pupae or as nymphs, spend part or all of their lives in water. In brooks you can often find the larvae of the caddis fly, with their artificial coverings of small stones, bits of wood, or pieces of leaves (illustration, p. 536).

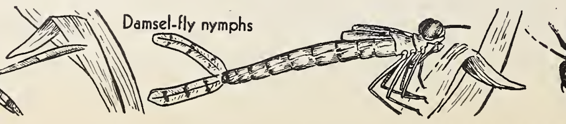
In your search of the bottoms of ponds you may come upon May-fly nymphs. These odd-looking animals live from one to three years in the water before they become fully mature. Upon reaching the adult state, they leave the water, shed their exoskeletons twice, mate, lay eggs, and die—all in the space of a few hours. Think of it: three years of growing up at the bottom of a pond, and only a few hours of adult life on land! In the ponds you are likely to find also the larvae of crane flies, mosquitoes, and beetles of many kinds, and the nymphs of damsel flies and dragon-flies.

By quickly turning over stones in rapidly running streams, or sometimes along the shores of lakes where the beach is washed by waves, you may find the nymphs of stone flies.

On the surface of quiet water you will be almost sure to discover adult water boatmen skimming about, or perhaps back swimmers darting here and there upside down. Also, you probably will see numerous swift whirligig beetles, whose name tells you how they move about on water.

For such studies you will need a "key" such as Needham and Needham's *Guide to Fresh-Water Biology* (The American Viewpoint Society, Inc., New York).





Ward's Natural Science Establishment

Suggest several types of reports which might be made on the living specimens collected from ponds

CHARACTERISTICS OF ARTHROPODS · Every arthropod has an exoskeleton.**[1] The exoskeletons of arthropods differ from the shells of corals and of clams, oysters, and other mollusks in important ways: (1) they cover every part of the animal completely; (2) they are jointed and thus allow separate parts of the animal to be moved freely.

The body of an arthropod is composed of segments, as are the bodies of the earthworm and its relatives, but with this important difference: some or all of the segments of an arthropod have appendages**[2] attached to them (illustration, p. 531).

The arthropods are the most completely organized of all the invertebrates. This statement means that arthropods have more organs and a wider division of labor than the members of any other group of animals without backbones.

ARTHROPODS AND MAN · **Insects.** Many kinds of insects are useful to man. On the whole, however, there are more insects that are harmful than helpful to the human race. A great majority of the kinds, however, are neither harmful nor helpful to man. Their life habits do not affect his in any way.

Bees, moths, butterflies, and many other insects distribute pollen among flowers and thus are important in the production of crops (illustration, p. 191). Some insects are of value to us because they prey upon enormous numbers of other insects which are harmful to man. Certain insects live as parasites on other insects which are enemies of man. Many insects, especially the larvae, do great service as scavengers by eating up vast quantities of decaying organic matter.

Some insects produce substances, such as silk, honey, lac, wax, and cochineal, which people use extensively.

Probably the most serious insect enemies of man are those that destroy his crops.[3] Scarcely any plants which people grow are free from insect enemies of one sort or another. Other insects, such as lice and fleas, are often parasites of domesticated (tamed) animals, and sometimes of man himself. Insects such as ants, cockroaches, flies, and weevils destroy our food, clothing, furniture, and other belongings. Biting insects, such as mosquitoes, bedbugs, and certain kinds of flies, cause much annoyance. Also, flies, mosquitoes, and many other insects carry disease germs,[4] which cause great suffering and loss of life.

Crustaceans. On the whole, the crustaceans are more useful to us than harmful. Crabs, lobsters, and shrimps are valuable as scavengers along the ocean shores. Crayfish and other crustaceans render similar service in rivers and lakes. Years ago people sometimes kept a few "crawfish" (crayfish) in their wells to "keep the water pure." Crayfish, however, sometimes do serious harm, especially in the Southern states. They sometimes weaken the levees along the river-banks by burrowing into them. Also, because at times they roam about on land, they sometimes do considerable damage by feeding upon the cotton and other crops.

Arachnids. Though many of the spiders and other arachnids benefit man by preying upon harmful insects, this group on the whole is probably more harmful than helpful. Some of the mites and ticks attack man and his domestic animals, and some of the ticks carry the germs of such a dangerous disease as Rocky Mountain fever and spotted fever.[5]

[1] *Exoskeleton* (ĕk sō skĕl′ē tŭn): the hard, protective covering of an animal, such as that of an insect or a crab.

[2] *Appendage* (ă pĕn′dĭj): an organ attached to the body of an animal, such as an arm, a wing, a leg, a tentacle, or an antenna** (ăn tĕn′ȧ); plural, *antennae* (ăn tĕn′ē).

[3] Pages 182–184. [4] Pages 309–312. [5] Page 287.

Three examples of each of the four common classes of arthropods · Topic for Individual Study: The characteristics and habits of the horse-shoe, or king, crab and the peripatus. These animals are considered by some zoologists to represent two other classes of arthropods

Scorpions can inflict painful but not dangerous stings. Of the spiders found in the United States and Canada, only the black widow and the tarantula are dangerous to man (illustration, p. 533). Contrary to common belief, however, their bites, especially the bite of the tarantula, are much more likely to be painful than fatal. Some kinds of spiders damage crops, and a few carry disease germs.

Other arthropods. Of the other classes of arthropods, none is of great importance to man. The centipede, however, which is common in the Southwestern states and the Hawaiian Islands, is able to inflict a painful, and occasionally even a dangerous, bite.

8. What Are Some Other Phyla of Invertebrates, besides the Most Familiar Nine?

Brief descriptions have now been given of all the phyla of invertebrates that are of special interest and importance to man. There are a few other great invertebrate groups (illustration, p. 534), which some zoologists consider to be phyla. Most people never hear about them, however, because (1) the animals belonging to these groups neither prey upon man nor live upon or within his body as parasites; (2) they do not compete with him for food; (3) they do not serve as an important source of his food; (4) man has not yet found ways of controlling them for his advantage; (5) they do not attack the plants and animals that man raises and controls; and (6) they do not injure or destroy his possessions.

Checking What You Know

BIOLOGICAL FACTS · (*Do not write in this book.*) **Pages 512–515.** **1.** The most numerous phylum of animals is the --?--.

2. *Few* protozoans have bodies consisting of more than a single cell.

3. One-celled animals can live only in *solid* materials.

4. Some protozoans are free-living animals, some are commensals, and others are --?--.

5. *No* protozoans live in colonies.

Pages 515–517. **6.** Sponges are the simplest of the *Protozoa.*

7. Most sponges live in either fresh or ocean water, and *few* of them are parasites.

8. There are *three* layers of cells in the body of a sponge.

Pages 517–519. **9.** *Few* coelenterates are terrestrial animals, and *none is a* parasite.

10. Coelenterates have bag-shaped bodies composed of *only one layer* of cells and having *two openings* into the body cavity.

Pages 519–523. **11.** Some worms are free-living, some are commensals, and some are --?--.

12. The bodies of all worms are made of *one less* layer of cells than are those of sponges and coelenterates.

13. Of the three phyla of worms, only the --?-- have segmented bodies.

14. Unlike the protozoans, the sponges, and the coelenterates, all the worms have *organ-systems.*

Nature Magazine

Male | Female | Female (under-side)

Male and female black-widow spiders · Topic for Individual Study: First aid in case of spider bite. Consult Bulletin E-245, Bureau of Entomology, United States Department of Agriculture, Washington, D. C.

Pages 523–524. **15.** The spiny-skinned animals are found only in *fresh* water.

16. Practically all the "spiny-skins" are *free-living* animals.

Pages 524–527. **17.** *Some* mollusks are terrestrial, *but none is* aquatic.

18. Many mollusks that are free-living as adults are *parasites* in their earlier stages of development.

19. State two ways in which all mollusks are alike, and state also the important respects in which they are different.

Pages 527–532. **20.** The most numerous invertebrates are the --?--, and the most numerous class of this phylum is the --?--.

21. State two characteristics of all arthropods.

22. Name four classes of arthropods.

BIOLOGICAL PRINCIPLES · **1.** Animals vary in structure from the comparatively simple to the very complex higher forms.

2. The more complex in structure an animal is, the greater is the division of labor among these various structures.

3. All living things are engaged in a constant struggle for energy.

4. The simpler forms of life are aquatic.

5. Living things become adapted to a wide range of habitats.

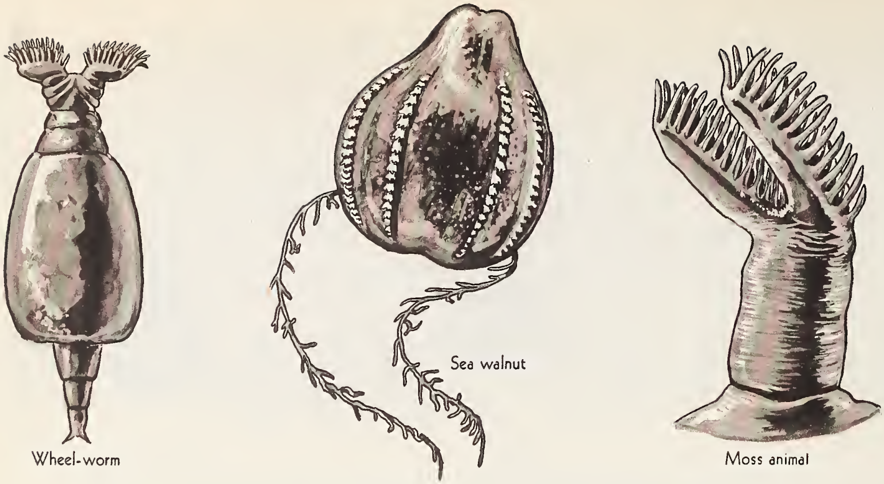
6. The greater the number of similar parts that a metazoan has, the more simple and primitive it is.

7. Every living thing has enemies among other living things.

8. Animals seek safety from predatory enemies in many ways, such as running, flying, swimming, or crawling away; remaining motionless; seeking shelter in a burrow, a crevice, or other space where the enemies cannot follow.

BIOLOGICAL TERMS

**appendage
**endoskeleton
**exoskeleton
**larva
**segment
**Metazoa
**Protozoa



Some zoologists place the wheel-worms (Rotifera[1]) in the scale of life between the roundworms and the segmented worms. Some zoologists consider the sea walnuts (Ctenophora[2]) a class of coelenterates. Most zoologists consider the moss animals (Bryozoa[3]) to be closely related to the wheel-worms. **Summary Question:** Which invertebrate phyla are of great importance, and which are of little importance, to man?

Applying and Extending What You Know

AS SCIENTISTS WORK AND THINK · While on a "hike" through an old orchard, a group of high-school boys and girls noticed that many clumps of tall grass had masses of foam on them.

"That's tree-frog spit," said Tom.

"No, not tree-frog spit, Tom," said Sue. "It's snake spittle."

"You are both wrong," said Ned. "It's cuckoo spit, or spittle."

Several others joined in, agreeing with Tom, Sue, or Ned. Each quoted a parent or somebody else as the authority for his or her statement.

"It certainly looks like spittle," said Sally; "but for my part, I don't care whether a tree frog, a snake, or a cuckoo put it there. All I care about is that I don't get into any of it."

"There are plenty of you who are sure that you know what it is," said Bill, "but you don't agree among yourselves. Maybe I can find out for sure."

He gathered several of the stems with the foam on them and took them back to the biology classroom. There he examined them carefully. Inside the foam he found tiny insect larvae. Miss Smith suggested that he look up *froghopper* in a "big" dictionary or a book on entomology (the study of insects).

Next day Bill reported to his class-mates what he had learned. But Tom, Ned, and several of the others still refused to believe that the foam had been put upon the grass by a certain kind of insect. They still insisted that it was "snake or frog or some other kind of animal spittle."

What scientific attitudes are indicated in this incident? Which of the elements of scientific method were used by Bill?

[1]*Rotifera* (rō tĭf′ẽr *ȧ*). [2]*Ctenophora* (tē nŏf′ō r*ȧ*).
[3]*Bryozoa* (brī ō zō′*ȧ*).

CONSUMER BIOLOGY · **1.** What mollusks and arthropods are offered for sale in your local food markets?

2. Find out from a jeweler what are the differences in structure, beauty, and value between "oriental" and "culture" pearls.

APPLYING YOUR KNOWLEDGE OF BIOLOGY · **1.** Rubber "sponges" are rapidly replacing the natural kind for many uses. What effect may this practice have on the sponge industry?

2. In North America, leeches are found only in fresh water. During the Second World War, however, soldiers fighting on tropical islands often found them on their bodies after traveling through jungles, even though they had not passed through ponds or streams. The leeches were on the leaves of bushes and other plants. What made it possible for them to live on plants in jungles?

3. Many animals seek safety in the porous bodies of sponges. One scientist found nearly seven hundred animals, belonging to fifteen species of worms, mollusks, and crustaceans, in twelve bath sponges that had been brought up from the ocean bottom near Florida. Small fishes of various kinds are known to "hide" among the tentacles of jellyfish (illustration, p. 520). Which of the principles stated on page 533 is most closely related to these facts?

4. How many ways in which man controls other living things for his advantage can you find in this chapter?

TOPICS FOR INDIVIDUAL STUDY · **1.** Select one or more of the phyla of invertebrate animals for further study. Consult a textbook of zoology or an encyclopedia.

2. Using a textbook of entomology, find out the names and characteristics of the various orders of insects, and how their life habits affect the welfare of man.

3. In a dictionary or a textbook of zoology find the derivations of the names of the various phyla.

4. What is *bèche-de-mer*, or trepang?

5. Of what three kinds of materials are the skeletons of different kinds of sponges composed? Are the shells of corals and mollusks and the coverings of the echinoderms composed of the same materials as any of these?

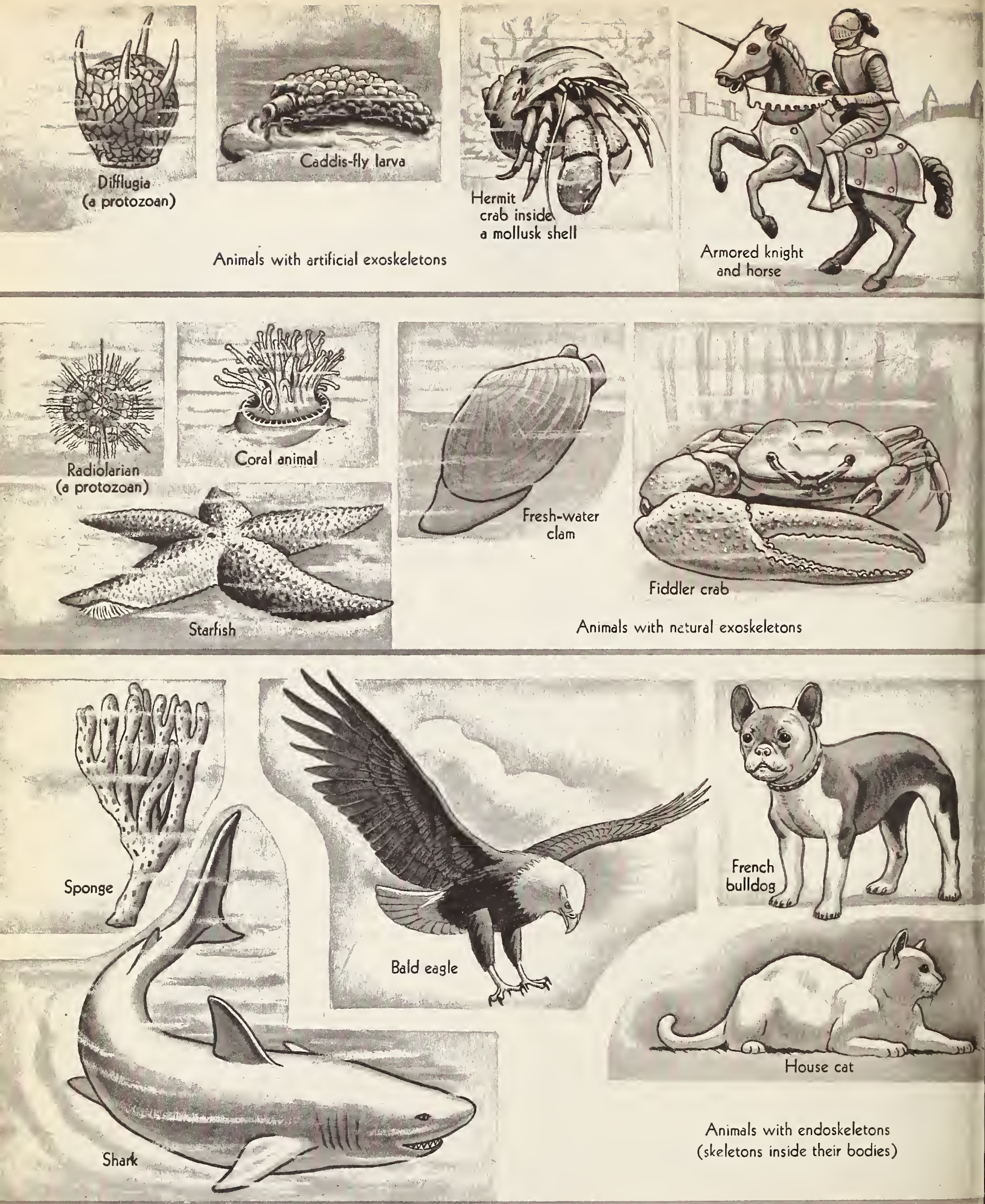
6. What are rock oysters? Why are they so called? Of what importance, if any, are they to man?

EXPERIMENT · What are some characteristics of certain common arthropods? Obtain individuals of as many different kinds of arthropods as you can—for example, a centipede, a millepede, a crayfish, a spider, and a grasshopper or other insect. Study their external structures. What characteristics do they all have in common? Why do you think they are placed in the same phylum, but in different classes?

WHY NOT BECOME A NATURALIST? · **1.** What can you learn by yourself about fresh-water sponges? Visit a pond, lake, or stream to look for fresh-water sponges. They will be small, white or brown masses clinging to twigs and stones in the water. Usually a fresh-water sponge is not more than one-half inch to an inch thick. Collect some for study in the laboratory. Put them into a container along with some water dipped from the place where you found them. Study them with a hand lens. Also, mount very small bits and study them with a compound microscope. Make a complete record of your observations.

2. What are some characteristics of the sow bug? This crustacean is often found under stones, boards, and logs where the soil is damp. Sow bugs are harmless and may be picked up with the fingers. Note what they do when exposed to the light. With careful notes or sketches, or both, record as many facts about the animal as you can discover—how many segments its body has, how many legs, what other appendages, etc.

BULLETIN-BOARD DISPLAY · Collect pictures of invertebrates from magazines and newspapers. Use textbooks of zoology to find out to which phylum each belongs. Whenever you can discover the scientific name, write it at the bottom of the picture. Arrange the pictures of the animals on the bulletin board by phyla. Save these pictures for a permanent file.



Probably most zoologists are agreed that only the arthropods have true exoskeletons. Which phyla that have been described are not represented by any animals here?

19

THE HIGHEST GROUP OF LIVING THINGS

1. What Are Some Important Facts about the Chordates, or Animals with Spinal Cords[1]?

The illustration on page 536 shows animals with various types of skeletons. Those in the first group make their own, artificial exoskeletons out of grains of sand, tiny pebbles, and other materials which they can secure in their habitats. Some of those in the second and third groups have shells, which serve in part as exoskeletons. Those in the last group have true skeletons—endoskeletons or exoskeletons.

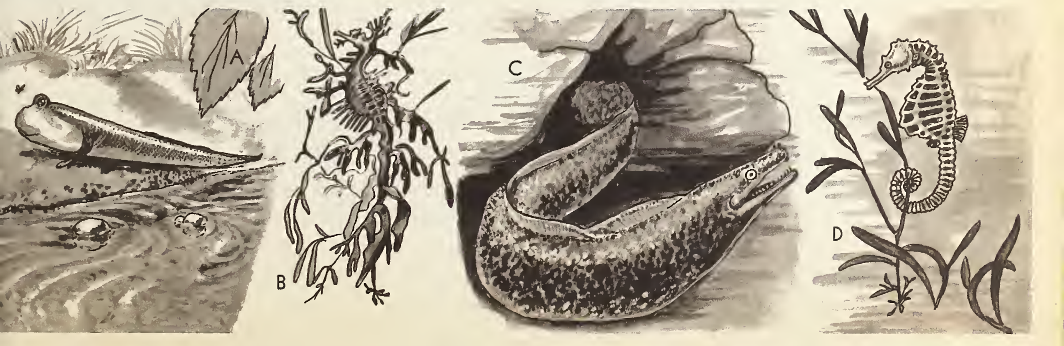
Few kinds of animals simpler than the chordates have structures that are endoskeletons or that resemble endoskeletons. None has a spinal cord protected by part of the endoskeleton, as the animals of the last group have.

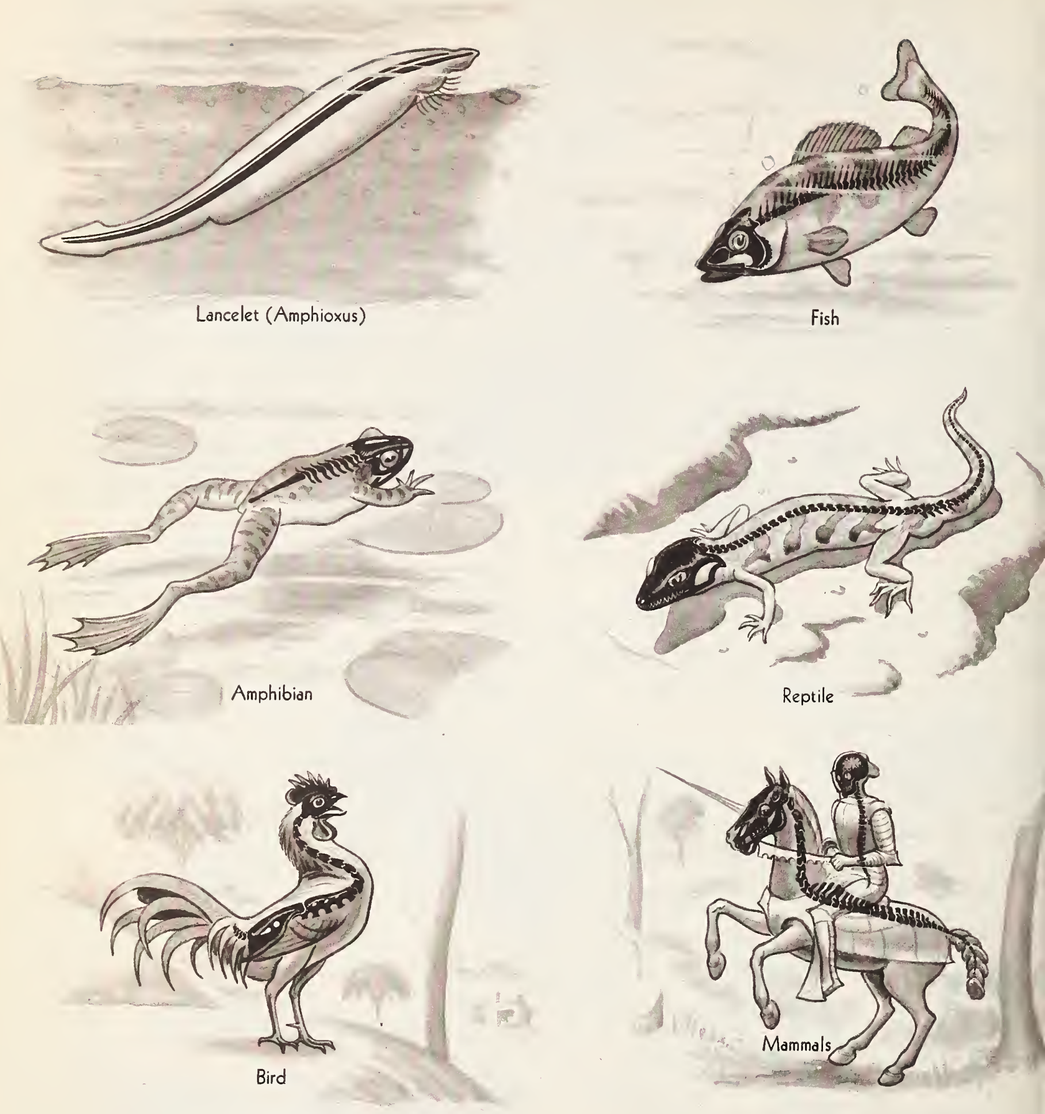
ANIMALS WITH BACKBONES · The illustration on page 538 shows animals belonging to the highest phylum of animals, the chordates. Every chordate has a spinal cord, made up of innumerable nerve cells, which extends along the length of its body on the dorsal**[2]

[1]The scientific name of this phylum is *Chordata* (kôr dā′tȧ). These animals are commonly called *chordates* (kôr′dāts).

[2]*Dorsal* (dôr′săl): related to or located near the back of an animal's body. The opposite of *dorsal* is *ventral*** (vĕn′trăl): related to or located near the front or lower side of an animal.

A. African mud-skipper. This six-inch fish leaves the water and skips about on the margin of the river, searching for insects. *B*. Australian sea horse, or sea dragon. This small species lives among the sea-weed, where its appearance affords it protective resemblance (see the Index). *C*. Moray, a savage tropical eel, which attains a length of several feet. It is a feared inhabitant of coral reefs. *D*. Sea horse. These two-inch or three-inch fish are the only known fish with prehensile tails. A prehensile tail is one that can be wrapped around objects, like a monkey's tail. **Topic for Individual Study:** Armored fish of past ages





Six chordates and five vertebrates · Topic for Individual Study: The lancelet, the shark, and certain other water animals resemble fish, yet are not true fish. In what respects are they like fish and in what respects different from them? (Consult a textbook of college zoology)

side. In the lancelet (illustration, p. 538), a two-inch, primitive ocean chordate, the spinal cord runs along a rod of cartilage*[1] called the notochord.[2]

In the members of the five highest classes of chordates (illustration, p. 538), the spinal cord runs lengthwise inside a spinal column, or backbone, made up of separate bones. These bones are the vertebrae.**[3] Hence these higher chordates are called vertebrates.**[4]

IMPORTANT CHARACTERISTICS OF VERTEBRATES · Of the chordates, only the five classes of vertebrates are of much importance to man, and these will be discussed separately in the sections that follow.

The vertebrates are not only the highest animals, but the highest of all organisms in the scale of life. They have the greatest numbers of different structures and hence the widest division of labor. They have the most highly developed organs, such as eyes, organs of hearing, and hearts, and they have the most complex organ-systems, such as digestive system, reproductive system, and nervous system. Of special importance is the fact that these highest organisms have the most highly developed brains.

Every vertebrate has, in addition to a spinal column, these characteristics which invertebrates do not possess: (1) a box-like structure of bones, called a skull, which encloses and protects the brain; (2) usually two pairs of appendages, or external organs, such as fins, legs and wings, or legs and arms; and (3) a complex system of bones inside the body.

2. *What Are Some Important Facts about the Simplest Vertebrates, the Fishes[5]?*

Most people are so familiar with the appearance of common fishes that they probably think that they would always be able to tell whether any animal they happened to see was or was not a fish. There are, however, many higher animals, such as seals and whales, which live in the oceans and look somewhat like fish, but which are no more closely related to fish than are dogs and cats. Sharks and skates also look like fish. Yet these animals are not fish, but are merely their close relatives. In contrast, there are some kinds of true fishes so strange in appearance that one would not be likely to recognize them as fish (illustration, p. 538).

CHARACTERISTICS OF FISH · In spite of the differences in appearance of the various kinds of fishes, most fishes have certain characteristics in common: (1) Their bodies have a protective covering of scales. These are modified skin structures. (2) Their bodies are adapted for swift locomotion through the water. They have a general form that causes little friction when the animals move through the water. Thus the bodies of fish are smooth, and are "stream-lined" in much the same way that the bodies of flying insects are stream-lined—they taper toward both ends, and they do not have projecting structures, such as hips

[1]*Cartilage* (kär′tĭ lĭj): a tough, elastic tissue; gristle.

[2]*Notochord* (nō′tō kôrd).

[3]*Vertebrae* (vûr′tē brē); singular, *vertebra* (vûr′tē brȧ).

[4]*Vertebrate* (vûr′tē brāt).

[5]The scientific name of this class of chordates is *Pisces* (pĭs′ēz).

and shoulders. Men have designed submarines and airships somewhat in the form of fish, to reduce friction. The bodies of fish are covered with a slimy substance, which greatly reduces friction. (3) Fish have two pairs of fins on their sides. These show the relationship of fish to other vertebrates. Thus the anterior,**[1] or forward, pair of fins (the pectoral fins) are homologous[2] to the front legs of a horse or a cat, and to the wings of a bird. The posterior**[3] pair, or those toward the rear (the pelvic fins), are homologous to the hind legs of a horse or a cat, and the legs of a bird. (4) Fish have an air-filled organ called an air bladder. Without this, they would sink to the bottom.

Most fishes lay eggs, but a few kinds bring forth their young alive. These kinds include the porgy, the sea horse, and the ocean perch. The young of all fishes resemble their parents rather closely.

Fish range in size from some kinds which, when mature, weigh a ton or more to others which, when full-grown, weigh only a minute fraction of an ounce. The smallest known vertebrate is a microscopic fish[5] that lives in Hawaiian waters.

Fish are cold-blooded animals. A cold-blooded animal is one that has a blood temperature, and hence a body temperature, which rises or falls as the temperature in the habitat varies. Thus the blood of a fish in a mountain stream formed by a melting glacier is about as cold as ice water. If the fish were put into a warm pond, the temperature of its blood would soon change so as to be about the same as that of the pond.

FISH AND MAN · From the days of ancient man to the present, fish have always served as an important part of man's food. Man controls fish for his advantage by propagatirg them (causing them to multiply) in hatcheries and by establishing various kinds in streams, lakes, and ponds where they have not previously lived.

3. What Are Some Important Facts about the Toads, Frogs, and Other Amphibians[4]?

During the Second World War you probably read about "amphibious tanks," "amphibious planes," and "amphibious operations." An amphibious tank is a tank that can travel both on land and on water. An amphibious plane is one that can take off from and land on either water or ground. An amphibious operation is one that involves both land and sea forces.

The word *amphibious* is derived from a Greek word meaning "living a double life." So is *amphibian* (illustration, p. 541). Like the amphibious war machines, the amphibians "live a double life," on land and in water. When young, they live in the water and breathe with gills, as fish do. But when they become adult, they live on land and breathe

[1]*Anterior* (ăn tēr′ĭ ẽr).

[2]Page 51.

[3]*Posterior* (pŏs tēr′ĭ ẽr).

[4]The scientific name of this class of chordates is *Amphibia* (ăm fĭb′ĭ *ȧ*). These animals are commonly called *amphibians* (ăm fĭb′ĭ ănz).

[5]*Pandaka pygmaeia* (păn′d*ȧ* kä pĭg mē′*ȧ*).

with lungs, like the higher vertebrates. Familiar amphibians that develop in this way are toads and frogs (illustrations, pp. 458, 538).

Some amphibians, however, such as the mud puppy (water dog), live under water all their lives. In contrast, the Surinam toad goes through its entire development out of water. It hatches from the egg and goes through the early stages of its development as a tadpole under the skin of its mother's back and comes forth as a small toad. Nearly all amphibians that, as adults, live out of water are found in damp habitats, where their skins are kept fairly moist (illustration, p. 538).

From these facts it will be seen that the amphibians are a group which are neither truly aquatic nor truly terrestrial. Instead, they are between the true water vertebrates, the fishes, and the true land vertebrates, the reptiles.

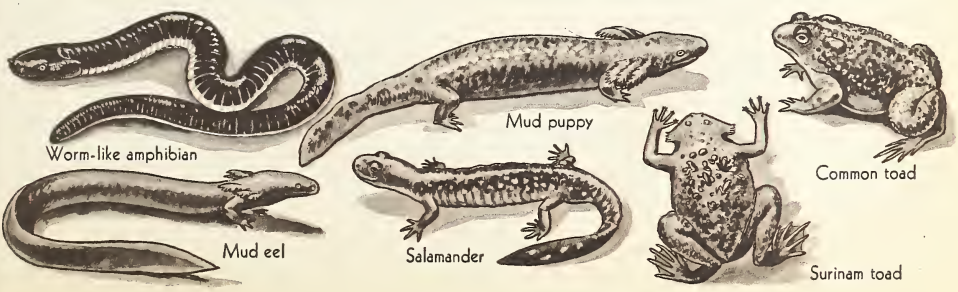
CHARACTERISTICS OF AMPHIBIANS · Amphibians are cold-blooded animals that hatch from eggs. The young do not resemble their parents. Adult amphibians vary in size from frogs an inch long to the giant salamander of Japan, which sometimes has a length of more than five feet. Some amphibians which lived ages ago were even larger than the Japanese salamander.

Most adult amphibians have smooth or warty skins without scales. Many are covered with slime. Some species are poisonous, but not in the same way that a rattlesnake is poisonous. They do not have a poisonous bite. Their poison is contained in glands[1] in the skin and is irritating and even dangerous to most animals that might attack them. Thus, if a dog bites a toad, it is likely to become sick from the poison in the toad's skin. One can handle a toad, however, with no danger whatever.

AMPHIBIANS AND MAN · The food habits of practically all amphibians are such as to make man's survival more easy. Most amphibians eat insects. Thus they reduce the numbers of animals that compete with man for the food that he raises. Toads and frogs are especially useful as insect-eaters. In parts of Europe toads are bought to put into gardens, where they may eat insect pests.

[1]*Gland:* a group of cells or an organ that produces a special substance.

Amphibians · Few large groups of animals vary as widely in appearance as amphibians. Can you think of a reason to explain why most large land amphibians are slow of movement?



New York Zoological Socie

Water moccasin (left), and coral snake (right). Can you think of any ways in which man controls snakes for his advantage (illustration, p. 2)?

4. What Are Some Important Facts about the Reptiles[1]?

Snakes are probably the kinds of reptiles with which you are most familiar. Other kinds are turtles, alligators, crocodiles, and lizards.

CHARACTERISTICS OF REPTILES · Reptiles are cold-blooded animals. Most of them are covered and protected with scales, which are modified skin structures. In addition to scales, turtles have a partial covering of shell. This is modified vertebrae partly and partly modified skin.

Although many kinds of reptiles spend all or part of their time in water, all breathe with lungs throughout their lives. Also, in contrast with the amphibians, they do not need to keep their skins moist. Some reptiles lay eggs, and others bring forth living young. All young reptiles resemble their parents.

SNAKES · People in general fear snakes, even though most snakes are harmless to man. In the United States there are only four kinds (genera[2]) that are dangerously poisonous (illustrations above and on pages 545 and 546). In Canada there is only one (rattlesnakes).

Rattlesnakes, copper-heads, and water moccasins are pit vipers. They are called pit vipers because each has a deep pit on each side of its head, which forms a triangle with the eye and the nostril. Unlike coral snakes, which have round bodies and heads, the pit vipers have thick, somewhat flat bodies and flat triangle-shaped heads. The coral snake has small, beady eyes with round pupils. Pit vipers have eyes with vertical pupils.

Rattlesnakes are distributed over southern Canada and over most of the United States. They are the only snakes that have rattles on their tails. These rattles consist of several flat, horny segments loosely joined. When disturbed, the snake vibrates its tail rapidly and thus causes the rattles to produce a buzzing noise (illustration, p. 546). Copper-heads and water moccasins will sometimes vibrate their tails in the same way when disturbed, though they have no rattles.

[1]The scientific name of this class of chordates is *Reptilia* (rĕp tĭl'ĭ *ȧ*).

[2]Page 55.

Copper-heads are native to a roughly defined area which includes southern Massachusetts, New York, parts of the Middle West, and most of the South. Water moccasins, or "cotton-mouths," live in the swamps and in and along the lakes and streams from North Carolina and from southern Indiana and Illinois to the Gulf of Mexico. Coral snakes are native in the South and in southern Arizona.

A few years ago a high-school pupil in Florida captured a coral snake and brought it to school in a fruit jar for study by the biology class. In some way the jar containing the snake was knocked off a desk and broken. The coral snake crawled out; and when the boy tried to capture it again, it bit him. The boy became sick at once, and for more than a week his life was in danger. Fortunately, however, the doctors who attended him were able to secure an "anti-venom," or antivenin,[1] a special kind of serum[2] used to combat snake venom, or poison. They gave him five injections of the serum, which enabled him finally to recover.

The coral snake is a small relative of the cobra (illustration, p. 354).

Although coral snakes have a more deadly poison than the pit vipers, they cause fewer deaths because they are rarely encountered. They burrow into the ground and are not often seen. They are sometimes turned up when fields are plowed.

TURTLES · Many kinds of turtles are aquatic. Others are terrestrial. The feet of turtles are modified in such ways as to make them well adapted to their habitats. Thus the giant sea turtles, which never come to land except to lay their eggs in the sandy beaches, have feet modified as paddles, which serve well for swimming. The gopher tortoise, which lives in the deserts of the Southwestern states, has claws adapted to locomotion on land and to burrowing into the sand. The painted turtle, which is found both in rivers and ponds and on land, has claws adapted to walking, but has also webs between its toes, adapted to swimming.

LIZARDS · If you were to see a "glass snake," what should you think it was (illustration, p. 552)? If you saw it close its eyes, you would know that it was a lizard, for snakes do not have movable eyelids. There are a few kinds of legless lizards besides the glass snake, but most lizards resemble the amphibians, except that they are covered with scales.

Lizards are common all over Canada and the United States, and, with the exception of one species, all are harmless. This exception is the Gila monster (illustration, p. 552), which is found in the deserts of the Southwestern states. Its poison fangs are in its lower jaw. Hence, when it bites, it turns over on its back, with the result that the poison flows down into the wound. Its powerful jaws do not let go, even though the head is cut off; and they can be pried apart only with great difficulty.

CROCODILES AND ALLIGATORS · Crocodiles and alligators are large, lizard-like reptiles. They are adapted for aquatic life in several ways: (1) the hind feet have webs between the toes, which aid in swimming; (2) the tail is somewhat flat and serves as a sort of paddle, in much the same way that a fish's tail does; (3) the eyes and nostrils project in such a way that the animal can float with only its eyes and nostrils above the water.

[1] *Antivenin* (ăn tĭ vĕn′ĭn).

[2] *Serum* (sēr′ŭm): a substance prepared from the blood to be used in the prevention or treatment of a disease.

PROTECTIVE COLORATION

MANY ANIMALS appear to us to resemble their habitats in color or appearance, or to resemble other animals in various ways. The most familiar type of such likeness, or resemblance, is protective coloration, or camouflage.[1] Animals having protective resemblance of this type blend with their habitats so well that they probably are not easily seen by either their enemies or their prey. Hence their coloration probably increases their chances of survival (illustrations, pp. 203 and 545).

The colors of most animals are fixed. Whether these animals are difficult to see depends, therefore, on whether they happen to be where their natural appearance blends with that of the surroundings. Some animals, however, change color. Such animals include most of the Amphibia[2]; a few fishes, such as flounders and their relatives; and some lizards, such as chameleons. Their skins become lighter or darker or change in shade whenever the light, the temperature, or the amount of moisture in the habitat changes. As a result, more often than not these animals blend better with their surroundings after the change than before it.

Rattlesnakes, copper-heads, and moccasins[3] have excellent protective coloration. Coral snakes, Gila monsters,[4] and some other poisonous reptiles, however, have an opposite sort of coloration, which is known as warning coloration. The coral snake is conspicuous with its vivid black, crimson, and yellow bands. The Gila monster is strikingly marked with yellow, black, and pink. Instead of serving as camouflage, or disguise, such coloration seems likely to "advertise" the animals possessing it. It may serve, therefore, to warn other animals against attacking them.

A type of protective resemblance which is believed to be related to warning coloration is illustrated by several species of harmless ringed snakes. These closely resemble the coral snakes in appearance. The chief difference is in the arrangement and widths of the color bands. It is believed possible that these harmless snakes have somewhat better chances of avoiding attack because of their resemblance to the poisonous coral snakes.

Protective resemblances are so numerous that many people accept them without question as adaptations having survival value. Caution is necessary, however, in accepting such a belief. It should be kept in mind that we decide whether an animal has protective resemblance merely by the way it looks to *us*. We judge that an animal that looks to *us* like its surroundings or like some other living thing must appear to other animals in the same

[1]*Camouflage* (kăm′ōō fläzh).
[2]Pages 540–541.
[3]Pages 542–547.
[4]Page 543.

Nature Magazine

Camouflage of a copper-head snake. Bulletin-Board Display: Cut out of magazines and newspapers illustrations showing various examples of protective resemblance

way. We assume that because certain animals escape our notice, they are just as likely not to be seen by their enemies. But we cannot be sure of that. We cannot prove it. It is a fact, moreover, that the enemies of an animal manage to find it no matter how perfect its protective resemblance appears to us to be. Many biologists therefore believe that protective resemblances of all types are probably less important as aids to survival than most people think.

Spring is an especially favorable season in which to observe protective resemblances, though they are to be seen at all seasons. Perhaps you can find a mother bird on her nest, a moth on tree bark, a green larva on a green leaf, or some other examples of protective resemblances in your "hikes," or wherever you may go. Keep a careful record of all such observations, stating, if you know or can find out, what the animal was, where it was, and what was the nature of its protective resemblance.

None of these reptiles is found in Canada. The American crocodile is found in no part of the United States except Florida. It occasionally grows to be nearly fifteen feet in length. The American alligator, much better known, is common in the Southeastern states. It has a broader, blunter snout and a thicker, heavier body than the American crocodile and is less dangerous to man. Some specimens grow to be sixteen feet long.

REPTILES AND MAN · The life habits of most of the reptiles make them useful to man. Common snakes and lizards especially are useful, for they destroy great numbers of harmful insects. Many snakes also prey upon such animals as rats, mice, and squirrels, which destroy crops. The food habits of snakes, however, do not always contribute to human welfare, because these reptiles prey upon birds that are useful to man. In some of the tropical islands of the Pacific, instead of keeping cats, the people sometimes make pets of boa constrictors to keep their houses free of rats and mice. In this country rodent-eating snakes, such as milk snakes, are useful animals in and about barns.

Though snakes kill few people in the United States and Canada, in some parts of

A diamond-back rattlesnake ready to strike · Most snakes have teeth which function in capturing prey. Poisonous snakes have, in addition, two hollow fangs. These are modified teeth. Each fang is connected by a duct (tube) to a venom (poison) gland. When the snake strikes, it forces the fangs deep into its victim. The venom is squeezed out of the glands, through the ducts, and into the wound. **Topic for Individual Study:** Antivenins. (Bulletins can be secured from the United States Department of the Interior)

United States Fish and Wildlife Service

the world, as India, they kill more people than does any other group of animals. A few of the large constrictors, which kill their prey by squeezing it to death, occasionally kill human beings, though rarely. The African crocodile is believed to have killed more people than any other kind of African wild animal. In spite of these dangerous reptiles, the group as a whole is of far more benefit than harm to man.

5. What Are Some Important Facts about the Feathered Animals, the Birds[1]?

There are more than fourteen thousand species of birds. Yet if you were to see an individual of any of these species, you would know at a glance that it was a bird. You could recognize it by its feathers, for no other animal has its skin structure modified to form feathers. You could recognize it also by its general structure and appearance, for all birds look much alike and a bird does not look much like any other kind of organism.

CHARACTERISTICS OF BIRDS · Birds are warm-blooded animals; that is, their blood temperature remains about the same, even though the temperature of the habitat may vary. Nevertheless they are able to live in the coldest regions, and some of them can fly in the frigid atmosphere several miles above the earth because their covering of feathers prevents the rapid loss of their body heat (illustration, p. 548).

All birds lay eggs. The young birds, upon hatching from the eggs, look much like their parents.

There is evidence which leads biologists to believe that birds are descended from ancient reptiles. Their feet and legs are covered with scales, which are modified skin tissue. Though no birds now have teeth, the earliest-known birds had teeth much like those of some of the reptiles today. These birds became extinct about twenty million years ago.

BIRDS AND MAN · Man controls the life habits of birds to a greater extent than those of any other great group of animals except the mammals. You can, no doubt, think of many examples.

6. What Are Some Important Facts about the Mammals[2]?

To most people the word *animal* means one of the mammals. When a farmer thinks of his "animals," he usually has in mind his cows, horses, sheep, and pigs, rather than his fowls or his hives of bees. The term *circus animals* brings to mind the trained horses and elephants and the caged mammals from all over the world. The term *wild animals* nearly always suggests wild mammals of the forests and jungles, such as tigers, wolves, wild boars, gorillas, and the like, rather than snakes or insects.

CHARACTERISTICS OF MAMMALS · There are at least four thousand kinds of mammals

[1]The scientific name of this class of chordates is *Aves* (ā′vēz).

[2]The scientific name of this class of chordates is *Mammalia* (mă mā′lĭ *ȧ*). These animals are commonly called *mammals*** (măm′ălz).

The structures of birds are adaptations to their food-getting, locomotion, and other life habits. **Bulletin-Board Display:** Collect and mount, on a large sheet, illustrations showing other adaptations of birds than the ones shown here; or make a series of drawings of the feet, wings, and beaks of various birds. Label each kind of bird and write below the label the life habit or habits to which the structure or structures are adapted

Platypus
Egg-laying mammals

Kangaroo
Pouched mammals

Shrew
Insect-eating mammals

Porcupine
Gnawing mammals

Moose
Hoofed mammals

Elephant
Trunk-bearing mammals

Dog Cat
Flesh-eating mammals

Sperm whale
Toothed whales

Gorilla
Highest mammals

Orders of mammals · Zoologists do not agree exactly about the number of orders that there are. How do you account for this statement?

now living (illustration, p. 549). There are, moreover, great numbers of other kinds which once were successful, but which lost the battle for existence and disappeared from the earth. Mammals have these characteristics: (1) They all feed their young with milk. This statement is true of even the few species that lay eggs. The milk is produced by the mothers by means of milk glands (mammary[1] glands). The name *mammal* is derived from a Latin word meaning "breast." (2) They are warm-blooded animals. (3) They are covered more or less completely with hair, which is a modified skin structure having functions similar to those of the feathers of birds and the scales of reptiles. (4) The young of all except the egg-laying members of the group are born alive, and all resemble their parents more or less closely. (5) Mammals breathe with lungs all their lives. (6) They have two pairs of appendages, which are variously modified for walking, grasping, swimming, and other functions.

MAMMALS AND MAN · No doubt you can think of many examples of man's controlling mammals for his advantage. A complete list of such examples would fill a large book.

Checking What You Know

BIOLOGICAL FACTS · (*Do not write in this book.*) **Pages 536–539. 1.** The *exoskeletons* of some animals are natural, and those of others artificial, but all *endoskeletons* are natural.

2. Every chordate has a spinal cord, but only a __?__ has a spinal column made up of separate bones called __?__.

3. State four unique characteristics of all vertebrates, that is, characteristics that no other kinds of living things have.

[1]*Mammary* (măm′*ȧ* rĭ).

Pages 539–540. 4. A typical fish has *scales*, covering its body; two pairs of __?__; a streamlined body; and an air __?__.

5. Fish are *warm-blooded* animals; that is, a fish's body *temperature* is about the same as that of its water habitat.

6. *All* fish lay eggs, and *all* young fish look much like their parents.

Pages 540–541. 7. A characteristic of all amphibians is (1) a scaly skin; (2) legs; (3) a tail; (4) a moist skin; (5) a land habitat.

Members of two orders of mammals not included on page 549 ·
The armadillo (left) is found from Texas to Paraguay. The scaly ant-eater (right) inhabits eastern Asia and Africa. How do you suppose that zoologists can be certain that these animals are mammals?

Wide World; American Museum of Natural History

8. *Few* amphibians are born alive, and *few*, when young, look like their parents.

9. Amphibians in general do more *harm* to man than *good*.

Pages 542–547. 10. *No* reptiles are born alive, and *few* young reptiles look like their parents.

11. Characteristics of all reptiles are (1) a scale-covered body; (2) lungs for breathing during their entire lives; (3) four legs; (4) a blood temperature about the same as that of the habitat; (5) poison glands.

12. There are only *three* kinds of poisonous snakes in the United States, and these are --?--, --?--, and --?--. The only poisonous snake in Canada is the --?--.

13. The only poisonous lizard in the United States is the --?--.

14. *More* reptiles are harmful to man than are useful.

Page 547. 15. A unique characteristic of birds is (1) legs covered with scales; (2) all young hatched from eggs; (3) a body covering of feathers; (4) young resembling their parents; (5) resemblance of one kind of bird to another.

16. Tell which of the following are warm-blooded animals: (1) chickens; (2) snakes; (3) toads; (4) sharks; (5) alligators.

Pages 547–549. 17. State six characteristics of the mammals.

18. Two unique characteristics of mammals are --?-- and --?--.

BIOLOGICAL PRINCIPLES · 1. From lower to higher forms of life there is an increasing complexity of structure, and this is accompanied by an increasing division of labor.

2. Living things have become adapted to a wide range of physical conditions.

3. The young of many kinds of living things resemble their parents, but the young of many other kinds do not.

4. Protective adaptations are an aid to survival.

5. Many organisms are able to survive because they are able to build artificial shelters.

6. The biological functions of color are to conceal, to disguise, or to make conspicuous.

7. Living things are not distributed uniformly or at random over the earth, but are found in definite zones or local regions where conditions are favorable for their survival.

8. Each species of living organism is adapted to live wherever it has become established.

BIOLOGICAL TERMS

**anterior	**mammal	**vertebra
**chordate	**posterior	**vertebrate
**dorsal	**ventral	

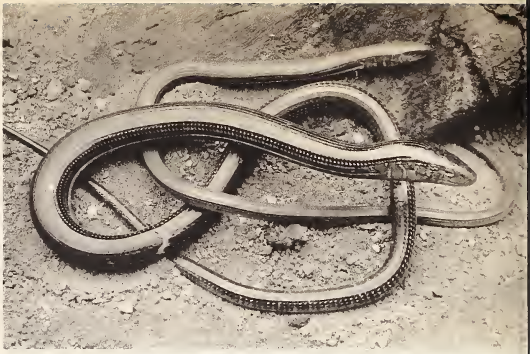
Applying and Extending What You Know

AS SCIENTISTS WORK AND THINK · 1. Which of the scientific attitudes must one possess in order to accept the biologists' statement that the animals shown in the illustration on page 537 are fish and that seals and whales are not?

2. There are a number of common superstitions about some of the vertebrates, of which perhaps you have heard: that if you handle a toad, you will get warts on your hands; that milk snakes and sometimes rattlesnakes suck milk from cows; that drinking whisky will cure snake bite; that snakes are slimy; and that snakes are able to "charm" birds and other prey and thus capture them easily. Perhaps you can think of others.

Which of the scientific attitudes relate to all these foolish beliefs?

CONSUMER BIOLOGY · 1. What kinds of fishes are offered for sale in your local markets as food? Which are fresh-water species and which



American Museum of Natural History; New York Zoological Society

A. Gila monster (left), and B. Glass snake (right). There are about three thousand kinds of lizards in the world, but only two are poisonous, the Gila monster and the Mexican beaded lizard. **Topic for Individual Study:** The largest living lizard, the dragon of Komodo

marine species? How do the prices per pound of the different kinds compare with those of pork, veal, lamb, and beef?

2. From which class or classes of vertebrates is each of the following products obtained: butter; cheese; eggs; caviar; frogs' legs; sweetbreads; tripe; leather?

3. The natives of many tropical countries prize snakes for food. Is canned rattlesnake meat sold in the food stores near your home? Is any other kind of reptile sold for food in the markets near your home?

APPLYING YOUR KNOWLEDGE OF BIOLOGY · **1.** Persons who fish for sport must return to the water the fish that are below "legal size." In doing so, they should always handle the fish only with wet hands. Why?

2. If a frog is left out of water for a day or so, it will die. Yet a frog never drinks water as you do. Can you explain why a frog dies if too long out of water?

3. Why must sea turtles and sea snakes (the only real sea serpents) come to land to lay their eggs? Why must toads go back into the water to lay their eggs?

TOPICS FOR INDIVIDUAL STUDY · **1.** How do turtles, tortoises, and terrapins differ? Consult a reference book such as R. L. Ditmars's *Reptiles of the World* (The Macmillan Company).

2. Look up *Harlequin* in a "big" dictionary. From the definition can you infer why certain kinds of coral snakes are called harlequin snakes?

3. What are the characteristics of the poisonous marine snakes, the real sea serpents? Consult an encyclopedia, a textbook of herpetology (the study of reptiles), or a "reptile book," such as Ditmars's *Reptiles of the World.*

4. If there are poisonous snakes in your locality, learn how to distinguish them from nonpoisonous ones. A reference book such as one of those suggested in No. 3 above or such as Hegner's *College Zoology* (The Macmillan Company) will give the desired information.

WHY NOT BECOME A NATURALIST? · **1.** If you enjoy fishing, keep a record of the different kinds of fish that you and your friends catch in the lakes and streams of your locality. Make a record also of other kinds of fish that you see in these bodies of water.

2. Look for various kinds of frogs, toads, sala-

manders, and other amphibians. Keep careful notes, with sketches, of the kinds that you find.

3. On your various "hikes" watch for different kinds of reptiles, such as lizards, turtles, and snakes. Be especially cautious if there are poisonous snakes or Gila monsters in your locality.[1] Make careful and complete records of your observations.

COMMUNITY APPLICATIONS OF BIOLOGY · 1. Make a list of the ways in which man, in your community, controls other vertebrate animals for his advantage. Remember that man has some control over wild animals, as well as over the domesticated ones. Keep this list where you can add to it as you discover new ways.

2. Visit a zoo to find out what kinds of vertebrates are kept there. Try to think of the class to which each kind of animal belongs. Study the ways in which the animals belonging to the same class are alike. If possible, find out how the various animals were obtained; what care they are given; whether or not they suffer from diseases; and other information about them. Make careful and complete records of what you discover.

[1]Pages 543 and 552.

BULLETIN-BOARD DISPLAY · Collect pictures of native and foreign animals belonging to each of the five classes of vertebrates. Arrange these pictures on your bulletin board, with the members of each class of vertebrates grouped together. Label each picture with the common and the scientific name. A dictionary will supply the latter. File the pictures so that they may serve as a permanent collection to which each biology class may add.

PANEL DISCUSSION[2] · *Topic:* Vertebrates are more important to man's welfare than invertebrates.

BIOLOGY IN THE NEWS · Find articles in newspapers or magazines about various kinds of vertebrates. Take notes on these articles as a basis for reports to be made in your biology class or science club.

[2]Page 116.

An invertebrate (scorpion, an arachnid) faces a vertebrate enemy (horned toad, a lizard) · Can you name other arthropods besides scorpions that have claws? How do you know from this picture that the horned toad is a lizard and not a toad?

Raymond W. Thorp

20

THE FOUR GREAT GROUPS THAT MAKE UP THE PLANT KINGDOM

1. What Are Some Important Facts about the Simplest Plants, the Algae and Fungi[1]?

Have you ever eaten sea-weed? Some kinds are edible. These are dried and are sold for food in Scotland and other parts of Europe and in many parts of the Far East. The plants known as sea-weeds are algae.

No doubt you have eaten mushrooms, and perhaps puff-balls. These plants are fungi. Though some fungi are deadly poisonous, various other kinds are prized as food, all over the world (illustration, p. 556). In France and in some other parts of Europe, certain fungi, called truffles, grow completely underground. Squirrels, pigs, and dogs locate them by their onion-like odor and dig them up for food. Truffles are considered a great delicacy by human beings and always sell at a high price. Consequently people make a business of gathering them. The truffle-hunter trains a pig or a dog to guide him to where the truffles are growing under the soil. Then he digs up the plants and gives the pig or the dog a piece of cheese as a reward for its help.

CHARACTERISTICS OF THE ALGAE AND FUNGI · The algae and the fungi together make up the lowest of the four phyla of plants (illustration, p. 512). They are the plants with the simplest structures. None of the members of this phylum has true stems or leaves. All the algae have chlorophyll and hence are independent plants because they can make their own food. None of the fungi, even certain molds that are green in color, has chlorophyll. Hence all fungi are non-green[2] plants.

The simplest plants are not all single cells or colonies of cells, as are the simplest animals, the Protozoa. Instead, they are found in a considerable variety of forms. Most of the species, however, and by far the greatest numbers of individual algae and fungi, are one-celled plants. The rest vary in their numbers of cells from relatively few to millions. Consequently, the algae and fungi vary enormously in size.

THE ALGAE · Most algae are aquatic plants. Some species can remain alive where it is dry, but they cannot carry on all their life activities except where there is abundant moisture. Most kinds live in the oceans, but many live in fresh water, in moist soil, and on moist surfaces of rocks and trees.

Some marine species and many fresh-water species are a vivid green. Most of the ocean

[1]The *algae* (ăl′jē)—singular, *alga*** (ăl′gȧ)—and the *fungi* (fŭn′jī)—singular, *fungus*** (fŭng′gŭs)—together make up the group of *thallophytes* (thăl′ō-fīts). The scientific name of this phylum is *Thallophyta* (thă lŏf′ĭ tȧ).

[2]Footnote 5, p. 45.

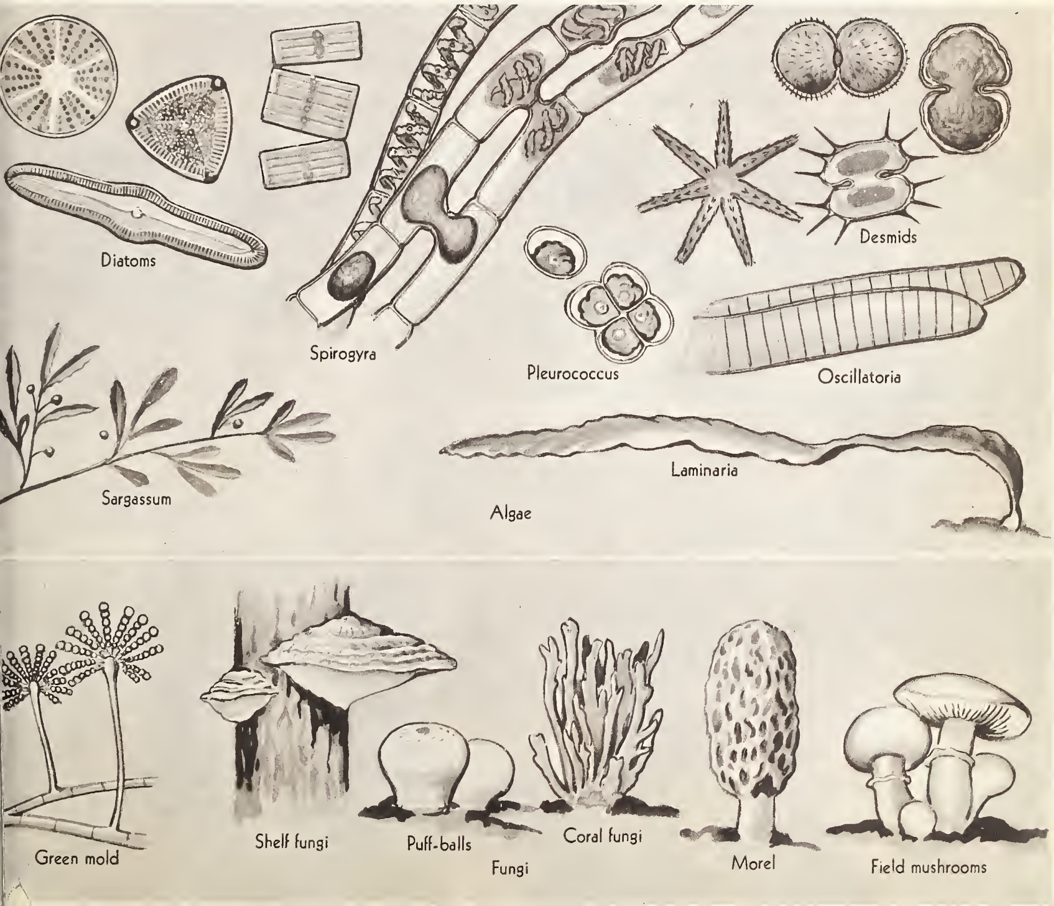
forms, however, are not green in color, even though they have chlorophyll, because they have other coloring matter which hides the green of the chlorophyll. Besides the green algae, there are the blue-green, the brown, and the red algae. The latter are of every shade of red from reddish-purple and purplish-black to bright pink.

Most one-celled algae are microscopic. In contrast, the largest single-celled organism known is a green alga called the "sea bottle." Sea bottles wash ashore on the Bermuda beaches, where they look like giant emeralds.

In the many-celled algae, such as the pond scums (the filamentous[1] algae), the cells are independent of one another, but are joined end to end in long, thread-like filaments,[2] or strands (illustration below).

[1]*Filamentous* (fĭl ȧ mĕn′tŭs).
[2]*Filament* (fĭl′ȧ mĕnt).

Algae and fungi · Scientists believe that algae were the first living things on the earth. There is evidence in ancient rocks that these simple plants inhabited the oceans at least half a billion years ago. Can you think of a reason why the fungi could not have been on the earth before the algae?



Some kinds of brown sea-weeds, called kelps, form heavy, shapeless masses. Some kelps grow to be hundreds of feet long. Certain antarctic kelps look like drooping trees several yards tall, with trunks more than half a foot thick.

DIATOMS · One group of independent one-celled plants is made up of the diatoms[1] (illustration, p. 555). They are probably related to the green algae. These plants have hard, glass-like coverings. They have an almost endless variety of forms, but each is constructed like a minute box with a lid.

Diatoms exist in almost any habitat where there are moisture and sunlight. In some parts of the ocean they are so numerous that a cup of sea water would contain more than a million of them. They are so small that it would take more than two hundred of average size, placed end to end, to measure an inch.

Diatoms, like the rest of the one-celled plants, are ancient organisms. They have lived in the oceans for hundreds of millions

[1]*Diatom* (dī′*ȧ* tŏm).

Ferns and mushrooms in a woods habitat · [E]It is never safe to eat any wild mushroom unless you know it is an edible one, because some of the most poisonous kinds closely resemble some of the best edible varieties. There are no simple tests by which to determine whether or not a mushroom is safe to eat. **Topic for Individual Study:** Commercial mushroom farming

J. Horace McFarland Compa

of years. As they have died, one by one, their shells have settled to the bottom. During ages of time their shells in places built up layers on the ocean floor, more than a hundred feet thick. Later, shifts in the earth's crust elevated these great deposits of microscopic shells above the ocean surface. The material in these deposits is now used for making metal polishes and tooth pastes, and for many other purposes.

THE FUNGI · The fungi include bacteria, molds, yeasts, blights, smuts, rusts, mildews, wilts, and mushrooms. Some rots, mildews, wilts, rusts, and smuts are parasites upon various fruit and vegetable crops. The fungi that are not parasites are saprophytes.**[1] The saprophytes among the fungi include most of the molds, mildews, yeasts, and mushrooms (illustrations, pp. 555 and 556).

LICHENS · The green or gray patches commonly seen on logs, rocks, and buildings are plants belonging to this phylum (illustration, p. 558). But they are neither algae nor fungi. Instead, they are both. If you examine through the microscope a small bit of lichen,[2] you will see round, green cells surrounded by threads. The green cells are an alga, and the threads are a fungus.

Lichens furnish examples of the sort of association known as symbiosis.*[3] Symbiosis differs essentially from the two other forms of association already described, namely, parasitism[4] and commensalism.[5] In parasitism the parasite injures its host. In commensalism the commensal[6] receives benefit from its host, but neither harms nor helps the latter. Usually the partners are "table-mates." They share the same food supply—that of the host. Sometimes, however, the commensal is able to survive more easily by being afforded shelter or by being carried about by its host. In symbiosis each organism is of value to the other. By being partners, both are able to survive more easily than either could alone. Thus the alga and the fungus that compose a lichen can survive in some habitats, such as the rocky surfaces of high mountains and the rocky shores of the arctic and antarctic regions, where practically no other plants have been able to live. The alga makes the food which both plants use. The fungus secures and stores the moisture needed by both.

Certain kinds of algae are known to form similar partnerships with some of the Protozoa (radiolarians), and also with a few of the Metazoa, including some kinds of sponges, corals, hydras, and flatworms. The animals in such plant-and-animal partnerships are transparent. If they were not transparent, no sunlight would reach the green plants inside them. Hence these plants could not make food and would die. Without the food contributed by these algae, their animal partners might find survival difficult or even impossible.

THALLOPHYTES AND MAN · Few algae affect man directly in any way. Some species, however, sometimes give the water supply an unpleasant taste or odor.

The one-celled marine algae are indirectly of great importance to man because these algae are the beginning units in innumerable food chains (illustration, p. 34). The one-celled algae that live at the ocean surface, and as far below as the sunlight penetrates, are numerous almost beyond belief. The number of such algae in six gallons of sea water

[1]*Saprophyte* (săp′rō fīt): a non-green plant that uses as food the dead bodies or the products of plants and animals. *Saprophytic* (săp rō fĭt′ĭk): caused by or relating to a saprophyte. *Saprophytism* (săp′rō-fīt′ ĭzm): the state of being a saprophyte.
[2]*Lichen* (lī′kĕn). [3]Page 97. [4]Page 19.
[5]Pages 513, 515. [6]*Commensal* (kŏ mĕn′săl).

Hugh Spen

Lichens are directly of little importance to man. Some, however, are indirectly of great importance as soil-makers, since they help to break up the rock surfaces on which they grow. How do these facts illustrate the biological principle By their life activities living things affect other living things?

may exceed the entire population of the United States. These algae are the food of many small ocean animals. These animals in turn are eaten by larger ones, and so on. Hence the algae indirectly serve as the food of the fish, the whales, and other ocean animals which man uses for food and other purposes.

The life habits of fungi are of such a nature that most of these plants are harmless and many are useful to man. Among the most useful ones are the bacteria that feed upon and thus destroy sewage[1] and other organic waste materials. Also of great benefit are the saprophytes, which cause the decay of dead plants and animals by consuming them as food.

The chief enemies of man among the plants of this phylum are the parasitic bacteria and other fungi that cause human diseases and diseases of domesticated plants and animals. Other important enemies are the saprophytic fungi, such as molds and mildews, which destroy man's possessions by using them for food.

Still other enemies among these non-green, saprophytic plants are those that compete with man for his food. For example, you are familiar, no doubt, with the molds and mildews that feed upon jellies, bacon, cheese, and many other foods.

A complete list of the ways in which man controls, with more or less success, the life habits of these thallophytes so that they

[1]*Sewage* (sū′ĭj): the waste materials resulting from the digestion of food and from other bodily processes.

either serve him or are unable to harm him would fill many pages. The most important of these ways are those that are effective in the control of disease. Important also are those that are bringing increasing success in our constant fight against the fungi that destroy our property.

Man has domesticated bacteria, yeasts, and molds, just as he has domesticated mammals and garden plants. There are now many factories where, in acres of trays and in enormous tanks, bacteria, yeasts, and molds in countless billions are "working" for him. Certain of these molds and bacteria are proving to be increasingly important aids in the conquest of disease.[1]

Bacteria are used in many commercial processes. Among these are the manufacture of butter, cheese, and leather, and the preparation of flax for linen-making. Certain kinds of molds are put into choice kinds of cheese to grow there and thus to produce desired flavors.

Yeasts use sugars for food and in the process produce carbon dioxide and alcohol.[3] Bakers put specially grown yeast plants into their dough to produce carbon dioxide abundantly. The carbon dioxide forms bubbles all through the dough and thus makes the bread "light" and porous. The alcohol, also produced by the yeast plants, evaporates and escapes during the baking. Yeasts are used extensively to produce alcohol in alcoholic beverages.

2. *What Are Some Important Facts about the Mosses and Liverworts[2] ?*

What people commonly call "moss" is not one plant. It is a solid mat composed of a great number of moss plants. Mosses grow abundantly in moist habitats all over the world. They are successful in many places where higher plants could not possibly survive. They grow not only on stumps and logs, but also on the ground in the deep shade of forests, on the surface of rocks, on the bark of living trees, in marshes and bogs, and sometimes on the bottoms of streams. Even in the heart of a great city, mosses are likely to be found successfully carrying on a hard struggle for life in cracks and depressions in old brick and stone walls, and on old roofs.

Liverworts are not so widely distributed as the mosses. Yet they are found in many habitats favorable to mosses, namely, on moist soil, on rocks, or tree trunks, and on old logs and stumps. They are likely not to be noticed, because the common kinds look like dark-green leaves lying on the ground. Some varieties that grow on tree trunks look like delicate mosses.

CHARACTERISTICS OF THE MOSSES AND LIVERWORTS · The members of this group are green plants, equipped with chlorophyll to make their own food (illustration, p. 561). Most of them are true terrestrial plants, though a few species are aquatic. They are more like the trees and the other higher plants than they are like the algae and fungi,

[1]Pages 327–331.

[2]The scientific name of this phylum is *Bryophyta* (brī ŏf′ĭt *ȧ*). These plants are commonly called *bryophytes* (brī′ō fīts).

[3]Page 567, "As Scientists Work and Think."

for most of them have simple organs that resemble leaves, stems, and roots. They have many more kinds of tissues and simple organs than the many-celled species of the lowest phylum (the Thallophyta).

The mosses and liverworts are enormous as compared with most of the one-celled algae and fungi, but are small as compared with most of the higher plants. They are rarely more than a few inches high. They cannot grow tall, because they do not have woody stem structures to support them, such as the higher plants have. Some liverworts that float on the surface of ponds and streams are no bigger than a pin-head. Those that grow on the ground are an inch or more across.

BRYOPHYTES AND MAN · The bryophytes are of little importance in relation to man's welfare.

3. *What Are Some Important Facts about the Ferns, the Horsetails, and the Club Mosses[1]?*

The coal we now burn was formed from tree-like plants that covered great areas of the earth, probably more than two hundred and fifty million years ago. None of those species of plants lives on the earth today. They became extinct ages ago. They were, however, the ancient ancestors of the present-day ferns, horsetails, and club mosses. The conditions when they lived were much more favorable to plants like them than conditions are today. Hence they grew to enormous sizes, many of them being almost a hundred feet tall.

Generation after generation of those ancient giants lived, died, and finally became buried in swampy land. Slowly, during ages of time, they were changed to coal. The long period of millions of years during which these coal plants lived is now known as the Coal Age (illustration, pp. 468–469).

HABITATS · The present species of this group are widely distributed throughout the Temperate and Torrid zones, and are especially abundant in the tropics. Different kinds grow in a wide variety of habitats. They are chiefly terrestrial, though some are aquatic. Many grow in moist places, such as the banks of streams and damp meadows. A few are successful in the shallow water of marshes and ponds. A few others manage to exist on the surface of rocks. Some tropical club mosses are air plants (epiphytes[2]). Their roots are not anchored in the ground, but instead are attached to the trunks and branches of trees.

CHARACTERISTICS OF THE FERNS AND THEIR RELATIVES · Common ferns of Canada and the United States range in height from a few inches to several feet (illustration, p. 556). The tree-like tropical species, however, sometimes grow to be fifty feet tall, with leaves twelve feet long. Some vine-like tropical ferns grow to be a hundred feet long.

Common horsetails have stiff, rough stems only a few inches high (illustration, p. 562). Some slender, vine-like tropical forms, however, may grow to be forty feet tall. These are like the vine-like ferns in being able to remain upright only when they are supported by trees.

The common club mosses are vine-like

[1]The scientific name of this phylum is *Pteridophyta* (tĕr ĭ dŏf'ĭ tȧ). These plants are commonly called *pteridophytes* (tĕr'ĭ dō fīts).

[2]*Epiphyte* (ĕp'ĭ fīt).

A, L. W. Brownell; *B*, Dr. William C. Steere

A, moss plants; *B*, liverworts. What paragraphs on pages 554, 559, and 560 supply facts that support this statement: "Mosses and liverworts have more extensive division of labor than algae and fungi"?

plants that grow close to the ground. They are not mosses, but they look more like mosses than like other plants. There are no large species living today.

The ferns and their relatives have chlorophyll and hence can all make their own food. They are more highly developed than the mosses and liverworts. They have true stems, roots, and leaves. Running through their stems is a simple organ-system of tube-like cells, called a vascular[1] system. Through this vascular system the sap**[2] passes to all parts of the plant.

All the plants of this group that grow in soil have under-ground stems; that is, parts or all of their stems grow below the surface of the ground. The stem of the common fern is entirely under-ground, and often is many feet long. The only parts of the plant that grow above-ground are the leaves.

PTERIDOPHYTES AND MAN · The members of this phylum are directly of little importance to man. Some of them, however, such as the ancient forms that were changed to coal, are indirectly of the greatest importance to man's survival.

[1]*Vascular* (văs′kū lẽr).

[2]*Sap:* the watery liquid, roughly corresponding to blood in animals, that brings dissolved food, minerals, and other necessary substances to the living cells of a plant and carries away their waste materials.

A, L. W. Brownell; *B*, Brooklyn Botanic Ga

A, horsetails, or scouring rushes; *B*, club mosses.[1] Which ending of the following statement do you consider best? The climbing varieties of these plants are (1) parasites; (2) scavengers; (3) saprophytes; (4) enemies of the trees upon which they climb; (5) commensals; (6) partners in symbiosis (symbionts). Justify your selection

4. What Are Some Important Facts about the Seed-bearing Plants[2]?

The seed plants make up the highest of the four great groups. They are the dominant plants, that is, the most successful ones, of the present age. They are able to live in almost all habitats where any other kinds of plants or where any animals can live, except on mountain heights where there is always snow, in the driest deserts, in the open oceans, in the deep parts of lakes and rivers, and on bare rocks. The seed-bearing plants are of greater importance to man than are the plants of the other three phyla. They are the main sources of food for ourselves and our domestic animals. They supply most of the materials for our clothing, our furniture, and our houses, and for paper and many other commercial products. Also, they provide quinine, digitalis, and many other important drugs.

[1]Pages 560–561.

[2]The scientific name of this phylum is *Spermatophyta* (spûr mă tŏf'ĭ tȧ). These plants are commonly called *spermatophytes* (spûr'mȧ tō fīts).

NAKED SEEDS AND ENCLOSED SEEDS · The seed-bearing plants are divided into two

great groups: (1) the gymnosperms[1] and (2) the angiosperms.[2] The members of the first of these two groups form naked seeds, that is, seeds not in any sort of pod or covering. The commonest plants of this group are the conifers,*[3] which produce their seeds in cones. Examples are firs, spruces, pines, sequoias, and other evergreens (illustration, p. 158). The members of the second group have true flowers and form their seeds in pods or other closed coverings.

The first group of seed-bearing plants, the gymnosperms, are perennials.*[4] A perennial plant is one that lives more than two seasons, and some of them, such as the great forest trees, live for several hundred or even a few thousand years. The gymnosperms have woody stems, which hold them upright, even after they die.

The second group, the angiosperms, includes not only many trees and bushes, which are perennials, but also many other plants, such as herbs, which are annuals,*[5] biennials,*[6] or perennials. An annual plant lives during only one year, and a biennial during only two. The herbs are plants with stems that contain relatively little woody tissue and hence are relatively soft. Such plants wilt when they die or when they do not have enough water.

INDEPENDENT AND DEPENDENT FLOWERING PLANTS · Practically all seed-bearing plants are independent organisms. There are, however, a few exceptions. The Indian pipe, a flowering plant with white stems and flowers, which grows in evergreen forests, is a saprophyte (illustration, p. 565). It has no chlorophyll. Hence it cannot make any of its food, but must secure it from decaying organic matter in the soil, as do all other saprophytes, such as the mushrooms, molds, bacteria, and other fungi.

The common mistletoe, the beautiful yellow-green or reddish-brown Christmas plant with the wax-like berries, is a partial parasite. It grows with its roots sunk into the branches of oak, apple, mesquite, and certain other trees. It has chlorophyll and makes part of its own food, but it takes water and minerals from its host.

Dodder, a common flowering plant and a troublesome enemy of our crop plants, is almost a complete parasite. It has no leaves and little chlorophyll. It twines about its host, and its roots grow into the host, from which it takes practically all its food.

The magnificent flowering plant *Rafflesia*[7] is a complete parasite. The whole plant is nothing but a flower and roots, without even a true stem, growing upon the root or sometimes the stem of its host.

There are several flowering swamp plants, air plants (epiphytes), and water plants that are carnivorous; that is, they capture animals as prey. These plants include the sundew, Venus's-flytrap, and pitcher plants, which catch insects, and the bladderwort, which grows under water and traps tiny water animals (illustration, p. 565). They have flowers or leaves so modified that they not only prevent the insects or other small animals that crawl or light upon them from escaping, but also digest them. They have chlorophyll and make most of their food, but secure some of their required food substances from the bodies of the animals which they trap.

SEED PLANTS AND MAN · Thousands of years ago man first began to control seed

[1]*Gymnosperm* (jĭm′nō spûrm).

[2]*Angiosperm* (ăn′jĭ ō spûrm). The two groups of angiosperms, the monocots and the dicots, are discussed on page 146.

[3]*Conifer* (kō′nĭ fĕr). [4]*Perennial* (pĕr ĕn′ĭ ăl).

[5]*Annual* (ăn′ū ăl). [6]*Biennial* (bī ĕn′ĭ ăl).

[7]*Rafflesia* (rā flē′zhĭ *a*); page 446.

plants for his advantage when he learned to raise food crops. Agriculture has been the most important industry ever since. A major reason why the Allied nations, in both world wars, were able to continue the struggle until they gained the victory was that they were able to grow sufficient food. In the present post-war period the growing of sufficient food crops has been and will long continue to be the world's most important problem. Whether this problem can be successfully solved is by no means certain.

5. What Are Some Important Facts about Some Living Things That Are neither Animals nor Plants?

A discussion of the kinds of living things would not be entirely complete, even though it included descriptions of every kind of animal and plant. It would need to include also some discussion of the "border-line" organisms.[1]

There is a relatively small number of these. They are simple living things that do not clearly belong to either the animal kingdom or the plant kingdom, because they are like animals in some ways and like plants in others.

ONE-CELLED AND COLONIAL FORMS · Perhaps the best-known of these "twilight creatures" is *Euglena* (illustration, p. 568). It is sometimes so numerous in barn-yard puddles as to make them green. *Euglena* is a one-celled organism that resembles in appearance several species of the Protozoa.[2] It is like most animals in having locomotion. It swims by means of one or more flagella, which it whips about. Also, like most one-celled animals, *Euglena* (or at least some of its close relatives) can take in minute organisms or solid particles of organic matter as food. *Euglena* is like the one-celled algae, however, in having chlorophyll. Thus, unlike any animal, but like all green plants, it can make part of its own food.

[1]Page 7. [2]Pages 513–515.

Some close relatives of *Euglena* form free-swimming colonies. These colonies consist of from two to perhaps fifty, though usually sixteen or thirty-two, separate one-celled organisms (illustration, p. 568). The single-celled members of such a colony carry on their life activities almost as if each lived by itself. Each cell can engulf food like an animal, and each has chlorophyll and therefore can make food like a green plant.

Volvox (illustration, p. 566) is another "border-line" organism. This creature is a colonial form which resembles both animals and plants in the same ways as do the other colonial forms just described. It is, however, more complex in structure than these others.

If you make a slide for studying protozoans, such as was suggested on page 41, you may find a volvox on the slide. It looks like a ball rolling over and over. It consists of about twelve thousand cells of a few different kinds, in a single layer on the outside of a hollow ball. All are connected by threads of protoplasm.

By far the most numerous kind of cell in *Volvox* has two hair-like flagella. These cells provide locomotion by all whipping their flagella at the same time and in the same way. These cells are able also to make food. Hence


B, American Museum of Natural History

A, Indian pipe; *B*, microscopic carnivorous water plants.

Topic for Individual Study: Carnivorous plants

none of them has to have the help of any other cells in the colony in order to remain alive. Other kinds of cells in the colony—for example, the reproductive cells—cannot make food for themselves. They must have a share of the food which the food-getting cells secure. Hence they are not independent of the others.

Because they have both independent and dependent cells, such colonial forms are thought of as being intermediate between the one-celled organisms and the many-celled organisms. *Volvox* is more like a metazoan than is any protozoan. Yet it has fewer different kinds of cells than are found in even the simplest of the Metazoa.

SLIME MOLDS · Slime molds are organisms that are shapeless masses of protoplasm. They are sometimes a foot across and two or three inches thick. Most of them are purple, green, yellow, pink, or white. The common species live usually on decaying organic matter, such as piles of leaves, old stumps, or rotting logs.

The slime molds furnish exceptions to the principle The bodies of living things are made up of one or more cells, because slime molds are not composed of separate cells. Instead, each is one undivided body of protoplasm containing numerous nuclei.

Slime molds are usually classified as fungi, for they have no chlorophyll. They are like some fungi in the way in which they reproduce (the process is too complex to be described here). In their mature state, however, slime molds are more like animals than like plants, because (1) they crawl like an ameba, and (2) because they engulf (surround) solid particles of organic matter for food, as an ameba does. In fact, they are probably more like the kind of organism that would result if great numbers of amebas were to flow together into one mass than they are like anything else.

"BORDER–LINE" ORGANISMS AND MAN · Some colonial forms related to *Euglena* and *Volvox* give drinking water unpleasant flavors or odors. Scientists have learned how to kill these organisms by putting certain chemicals into the reservoirs. A few parasitic slime molds attack certain crop plants.

With these and perhaps a few other exceptions, the "border-line" organisms are not known to affect man's living in any way. One can, however, agree with the boy who, two hundred years ago, wrote in the margin of his book that described the wonders of plant life and animal life as they were then known,

In earth and air and sea
Strange thinges ther be!

Checking What You Know

BIOLOGICAL FACTS · (*Do not write in this book.*) **Pages 554–559. 1.** A characteristic of all algae and fungi is (1) leaves; (2) stems; (3) chlorophyll; (4) single-celled bodies; (5) very simple structures.

2. Algae differ from fungi in having (1) no leaves; (2) no stems; (3) chlorophyll; (4) one-celled bodies; (5) a moist or fluid habitat.

3. *Many* algae are independent plants; that is, they are able to make their own food.

4. Every fungus is either a parasite or a __?__, and is therefore *a dependent* plant.

5. A lichen is composed of a __?__ and a __?__ living together in partnership.

6. Diatoms are *many*-celled *fungi.*

7. Many of the *algae* are bacteria and other organisms that cause diseases.

8. Many kinds of *fungi* are enemies of man because they destroy his food and other possessions.

9. Yeasts can change sugars into *oxygen* and *alcohol.*

Pages 559–560. 10. Most mosses and liverworts are *land* plants. *Few* of them live in moist habitats.

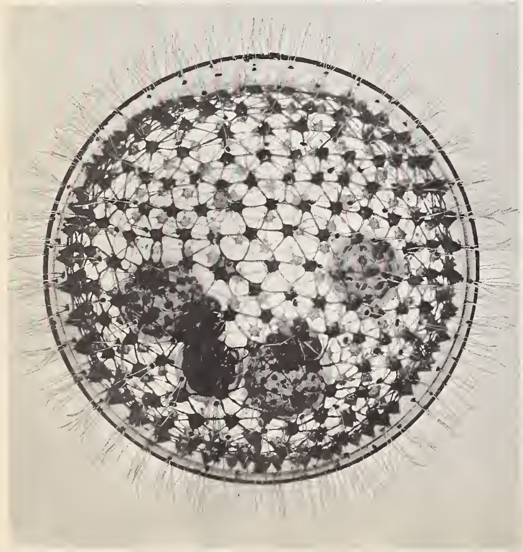
11. Mosses and liverworts differ from algae and fungi in (1) having chlorophyll; (2) being saprophytes; (3) being of great importance to man; (4) having one-celled bodies; (5) having simple organs.

Pages 560–561. 12. Coal has been formed from the bodies of the ancient ancestors of the (1) algae; (2) mosses; (3) liverworts; (4) fungi; (5) ferns and their relatives.

13. The ferns and their relatives differ from all the algae and the fungi and from the mosses and the liverworts in (1) having chlorophyll; (2) having true stems, roots, and leaves; (3) grow-

In *Volvox* there is a tendency toward division of labor; yet there is not true division of labor. Explain

American Museum of Natural History



ing in moist habitats; (4) being microscopic; (5) being of little importance to man.

14. All the ferns, horsetails, and club mosses are independent plants because they can make their own __?__.

15. The stems of ferns, horsetails, and club mosses grow partly or wholly under *water*.

Pages 562–564. **16.** A unique characteristic of all the plants of the highest plant group is that they have (1) chlorophyll; (2) roots, stems, and leaves; (3) flowers that produce seeds; (4) cones; (5) many years of life.

17. The *angiosperms* have true flowers and produce seeds that are enclosed in a protective structure.

18. *Some* seed-bearing plants are independent; *none* are parasites; *some* are saprophytes; and *some* capture animals as prey.

Pages 564–566. **19.** "Border-line" organisms differ from all animals in being able to (1) make part of their food; (2) swim; (3) capture prey or use parts of dead plants or animals as food; (4) live only in water; (5) live in colonies.

20. Slime molds are more like *algae* than like any other kind of organism, but they resemble *amebas* in the way in which they move about and take in food.

21. In a volvox the *reproductive* cells do not depend on the other cells in order to survive.

BIOLOGICAL PRINCIPLES[1] · **1.** Plants show an increasing complexity of structure from the algae and fungi to the seed plants.

2. Cells are organized into tissues, tissues into organs, and organs into organ-systems, and thus are better able to carry on the functions of complex organisms.

3. Many plants can live in water or in a moist habitat.

4. Most plants are independent organisms.

5. The kinds of living things change from age to age.

6. Every living thing has its enemies.

7. In order to survive, some plants and some animals form associations, examples of which are parasitism, commensalism, and symbiosis.

8. From the lower to the higher forms of life the body structure becomes more and more complex, and there is more and more division of labor.

9. Species not fitted to their environment will finally become extinct.

10. The environment acts on living things, and living things on the environment.

11. All living things die, but life continues from age to age.

BIOLOGICAL TERMS

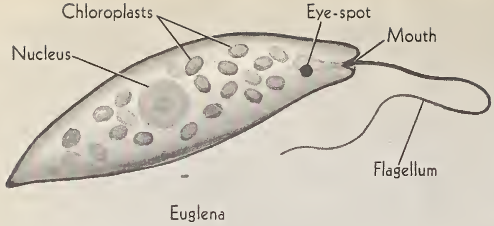
**alga **fungus **saprophyte

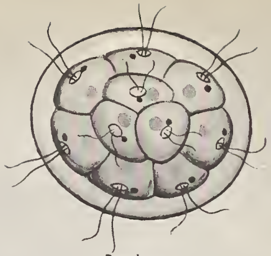
Applying and Extending What You Know

AS SCIENTISTS WORK AND THINK · The ancients knew, several thousand years ago, that "leavened" bread, baked from dough that had stood for a while, was different from "unleavened" bread, baked from dough as soon as it was made. They did not know, however, that the difference was due to "wild" yeasts that had fallen into the dough, along with other dust from the air. Can you outline an experiment by which you could find out whether the air in your home or in the school-room contains wild yeasts? First, study the experiment on page 568. Indicate which of the elements of scientific method you would use.

CONSUMER BIOLOGY · **1.** It is now possible to buy a household spray for the control of mildew. Upon what kinds of articles in the home should this spray be used?

[1]Page 37.





Both these organisms are sometimes classified as protozoans and sometimes as algae. Can you state one or more reasons to justify each of these classifications? Can you find a volvox, colonial protozoans, and a diatom in illustration *B*, p. 565?

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2. How many plants and their products that you can buy in food stores and drug-stores can you list in three minutes?

APPLYING YOUR KNOWLEDGE OF BIOLOGY · **1.** In what ways are marine and fresh-water algae of indirect importance to man?

2. What is meant when it is said that a plant or an animal is a "higher" or a "lower" organism?

3. William Beebe tells of a strange partnership of fishes which he observed from his bathysphere (illustration, p. 58). One kind of parrot-beaked fish lives upon small animals which it finds in the hard formations of coral reefs. In breaking off and crushing bits of coral, the fish's jaws, teeth, and gills become covered with coral fragments. At this point the fish remains motionless. A school of smaller fish of another species quickly approaches, and these fish remove all the coral bits. The parrot-beaked fish benefits by being freed of the coral fragments. Its small partners find bits of food among the coral fragments.

Is this partnership an example of parasitism, saprophytism, symbiosis, or commensalism? Justify your answer. Consult the Index and the Glossary, if necessary, in reviewing the meanings of these terms.

Can you explain how the partnership just described is an example of ecology?[1]

[1]Page 7.

4. The following is the only *known* example of its kind of relation between living things: The four-inch-long male of one kind of deep-sea angler fish attaches itself by its mouth to the underside of the four-foot-long female. After a short time the connection becomes permanent. The blood streams of both fish become one. From that time on, the male is nourished by the blood of the female for as long as either of them lives.

Is this partnership an example of saprophytism, symbiosis, parasitism, or commensalism? Justify your answer.

Do you think that this partnership is an example of ecology? Justify your answer.

EXPERIMENT · Why is yeast used in bread-making? Put into each of two containers a cupful of flour. Stir a quarter of a cake of prepared yeast into a quarter of a cup of warm water. When the mixture is "smooth," add to it a quarter-cup of warm water. Add this half-cup of water to one of the portions of flour and mix the water and flour into a dough. Add a half-cup of warm water to the other portion of flour and mix them too into a dough. Label the containers so that you can be sure which contains the yeast.

Put both portions of dough side by side in a fairly warm place. Observe both portions several hours later and again the next day. Do the two portions differ? If so, how?

If possible, bake the two portions of dough in the same oven at the same time. Do they differ after baking? If so, how? Can you answer the question with which this experiment begins?

How many of the elements of scientific method can you identify in the directions for this experiment?

WHY NOT BECOME A NATURALIST? · **1.** What can you find out about the mushrooms of your locality? Secure bulletins on mushrooms from the department of agriculture of your state, province, or Federal or Dominion government. Make a careful study of the mushrooms that you find growing in the woods and meadows and on lawns. Spring and fall are the seasons when wild mushrooms are most plentiful, though you will find them in the damp woods during the summer also. Do not taste any that you find. If possible, make studies of the spores of various specimens with a compound microscope. You can secure the spores by putting the cap of the mushroom, with the under-side down, on a sheet of white paper, and leaving it there for a few hours. When you lift the cap away, the spores will remain on the paper. With a knife blade you can scrape off some of the spores onto a slide. Make careful notes and sketches of all that you learn.

2. What kinds of liverworts, mosses, ferns, and conifers grow near your home? If possible, use the appropriate books listed at the end of this chapter to identify the plants that you find.

3. How completely can you list the flora, that is, all the kinds of plants, in your front or back yard?

PANEL DISCUSSIONS · Directions for conducting panel discussions will be found on page 116.

1. Topic: Everybody can profit by having some definite knowledge of the various groups of plants and animals.

2. Topic: The algae are more important to man than are the fungi.

3. Topic: The algae and fungi are together more important to man than the protozoans.

4. Topic: The angiosperms are more important to man than the gymnosperms.

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ELEMENTS OF SCIENTIFIC METHOD

IN SOLVING your own everyday problems, you can use the same method by which scientists solve their problems. Here are the elements of scientific method. Often you can solve a problem without using all the elements, or steps.

1. The scientific method starts with a problem, or question—something that you wonder about or would like to "find out about."

2. Decide exactly what the question, or problem, is and state it clearly.

3. "Marshal your facts." Think of all the facts you can that might suggest an answer or that might otherwise relate to the problem.

4. Think of as many possible answers to the problem as you can. Scientists call this step "making hypotheses."

5. Select from these possible answers, or hypotheses, the one that seems to you most likely to be the right one.

6. Carefully plan an experiment or a series of observations to find out whether the answer that you have selected is really the right one. Often the plan of an experiment will need to include a "control" (see Glossary). The experiment without the control and the same experiment with the control included must be exactly alike except for just *one* part, the "experimental factor." By introducing a control you will greatly reduce the possibility that the results of your experiment are due to chance.

7. Carry out the experiment or the observations with great care according to your plan.

8. Evaluate your procedures—study what you did, in order to discover possible defects, errors, or omissions.

9. Perform the entire experiment again or an improved one or a new one, or observe another group of plants or animals, to find out whether you get the same results a second time. This second trial is called a "check experiment."

10. Draw an inference, or conclusion, or make a new hypothesis or a general statement (principle), which will be the answer to your original question that the results of your experiment or your observations seem to you to justify most strongly.

11. Use what you have thus learned, whenever you can, in solving future problems.

SCIENTIFIC ATTITUDES

HERE ARE the scientific attitudes, which not only scientists, but also everybody else should strive to possess, and which are valuable not only in the study of biology, but in all our daily living:

1. A lively curiosity about the world in which we live.

2. The firm belief that nothing, not even the strangest and most mysterious occurrence, ever does happen or could possibly happen without a cause.

3. The belief that truth itself never changes, but that our ideas of what is true are certain to change in many respects as our knowledge becomes more exact and complete.

4. An unwillingness to accept any statements as facts unless they are supported by sufficient proof.

5. The determination not to believe in *any* superstitions.

6. The determination not to try to solve our problems in a careless or hasty way, but to make and carry through complete and careful plans for solving them.

7. The determination always to make our observations carefully and accurately.

8. A willingness to weigh all the evidence and to try to decide whether it really relates to the matter under consideration, whether it is sound and sensible, and whether it is complete enough to justify a conclusion.

9. A determination not to jump to a conclusion or to base a conclusion upon one or a few observations, but to seek evidence as long as may be necessary in order to find a true answer to a problem.

10. A preference for gathering our own facts by experimenting and observing, but a willingness to use the results and facts obtained by others.

11. A willingness to change an opinion or a conclusion if later evidence shows it to be wrong.

12. The intention to respect other people's ideas, opinions, and ways of life that are different from our own.

13. The determination not to allow our judgments to be influenced by our likes and dislikes.

GLOSSARY

In "This Book and You" (pp. xiii–xv) is a discussion under "Extending Your Vocabulary," which includes suggestions for using this Glossary. The biological terms marked with two asterisks, here and in the body of the text, are the "essential" terms. Those marked with one asterisk are the "important" terms. The number or numbers following each definition direct you to a page or pages on which the term is further defined or is explained. An asterisk following a page number indicates that the term is made clear on that page by a label or a diagram or in the legend of an illustration.

You will be able to locate readily in the Index the definitions and explanations of many terms which, because of limited space, could not be included in this Glossary. Such terms are indicated by *def.* preceding the page reference; as, "Annuals, *def.*, 563."

The sounds represented by the various symbols used in the pronunciations are indicated by the following words: āle, ădd, ärm, ȧsk, sofȧ, ēve, ĕnd, makẽr, īce, ĭll, ōld, ôrb, ŏdd, cūbe, ûrge, ŭp, fo͞od, fo͝ot, cultu̮re.

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abdomen** (ăb dō′mĕn): in man and other mammals, the portion of the body containing the stomach, liver, intestines, etc.; in insects and other arthropods, the rear one of the major sections of the body (p. 240).

absorption** (ăb sôrp′shŭn): the act or process by which a liquid, a gas, or energy (as heat or light) is taken into a body; or by which digested food passes through the walls of the alimentary canal into the blood or the lymph (p. 238).

adaptation** (ăd ăp tā′shŭn): a modification (change) of structure or behavior which fits an individual plant or animal to live successfully, or enables a kind of plant or animal to continue to exist in its environment (p. 23).

adrenal (ăd rē′năl) **gland:** one of a pair of glands near the kidneys, which produce the hormone adrenalin (p. 292).

alga** (ăl′gȧ); *plural,* **algae** (ăl′jē): a simple green plant belonging to the great group, or phylum, of simplest plants (the Thallophyta) (p. 554).

alimentary (ăl ĭ mĕn′tȧ rĭ) **canal**:** the digestive tube of an animal (p. 231).

allergy** (ăl′ẽr jĭ), or **hypersensitization** (hī pẽr-sĕn sĭ tĭ zā′shŭn): a condition in which a person's health is affected by pollens, certain foods, or other substances (p. 296).

alternation (ôl tẽr nā′shŭn) **of generations** (jĕn-ẽr ā′shŭnz): reproduction in which an asexual stage and a sexual stage follow each other in succession, each stage, or generation, producing the other, and the two together making a complete life cycle (p. 442).

alveolus (ăl vē′ō lŭs); *plural,* **alveoli** (ăl vē′ō lī): one of the small, bag-like structures that make up the lung tissue (p. 262).

ameboid (ȧ mē′boid): like an ameba in appearance or movements (p. 47).

amino (ă mē′nō) **acid*:** one of the simpler nitrogen compounds into which protein foods are broken down (chemically changed) by digestion, and from which living cells build their special proteins (p. 203).

Amphibia (ăm fĭb′ĭ ȧ), or **amphibians*** (ăm fĭb′ĭ-ănz): the group (class) of backboned animals (vertebrates) that includes the frogs, toads, and salamanders, which breathe in early life with gills, but most of which, as they become adults, develop lungs (p. 540).

anatomy* (ȧ năt′ō mĭ): the construction or the structures of a plant or an animal; the branch of biology dealing with plant and animal structures (p. 207).

angiosperm (ăn′jĭ ō spûrm): any flowering plant whose seeds develop in a closed ovary (p. 563).

Annelida (ă nĕl′ĭ dȧ), or **annelids** (ăn′ĕ lĭdz): the one of the three great groups, or phyla, of worms which includes earthworms and leeches, whose bodies are composed of ring-like divisions, or segments (p. 523).

annual*: a flowering plant that lives its entire life during one growing season (p. 172).

annual ring: the ring-like end of the cylinder of woody tissue which results from one year's

growth of a dicot or an evergreen tree or shrub and which is visible on the end of a stump or log (p. 164).

antenna (ăn tĕn'*ȧ*); *plural,* **antennae** (ăn tĕn'ē): one of the "feelers," or jointed sense organs, on the head of an insect or other arthropod (p. 388).

anterior** (ăn tēr'ĭ ẽr): near or toward the head or the forward portion of an animal; the opposite of *posterior* (p. 540).

anther* (ăn'thẽr): the organ on the tip of a stamen of a flower, in which the pollen is formed (p. 447).

antibody** (ăn'tĭ bŏd ĭ): one of several kinds of chemical substances produced by the body cells of an organism, which help the organism to resist attacks by disease germs (p. 307).

antiseptic* (ăn tĭ sĕp'tĭk): any substance which kills disease germs or prevents their reproduction (p. 318).

antitoxin** (ăn tĭ tŏk'sĭn): a substance produced by the body cells which counteracts the toxins, or poisons, produced by disease germs (p. 307).

antivenin (ăn tĭ vĕn'ĭn): a serum injected into the body to help it to overcome the effects of snakebite poisoning (p. 543).

aorta (ā ôr'tȧ): the largest artery in the human body, and the one through which blood is forced, by the heart-beat, from the left ventricle of the heart to smaller arteries branching throughout the body (p. 258).

appendage** (ă pĕn'dĭj): an external, usually jointed organ of an animal, as a fin, wing, leg, mouth part, or antenna (p. 530).

aquatic** (*ȧ* kwăt'ĭk): having to do with water or living in water (p. 28).

Arachnida (*ȧ* răk'nĭ d*ȧ*), or **arachnids** (*ȧ* răk'nĭdz): the group (class) of arthropods having four pairs of legs, as spiders, scorpions, mites, and ticks (p. 530).

artery** (är'tẽr ĭ): any blood vessel through which blood flows away from the heart (p. 258).

Arthropoda (är thrŏp'ō d*ȧ*), or **arthropods*** (är'thrō pŏdz): an animal, such as an insect, a spider, or a lobster, that belongs to the great group, or phylum, Arthropoda; whose body is made up of segments (sections, or divisions) and is protected by an exoskeleton; and which has jointed legs and other appendages (p. 530).

asexual** (ā sĕk'shōō ăl): without sex (p. 428).

asexual reproduction (ā sĕk'shōō ăl rē prō dŭk'shŭn): reproduction by any one of several methods involving only a single parent and therefore not involving sperms and eggs (p. 428).

assimilation** (ă sĭm ĭ lā'shŭn): the process by which digested food is made into protoplasm by and within the cells (p. 261).

auricle* (ô'rĭ kl: a chamber of a vertebrate's heart into which blood flows from the veins (p. 247).

autonomic (ô tō nŏm'ĭk) **nervous system:** that part of the nervous system which regulates the glands and the involuntary muscles (those not controlled by the will) (p. 381).

axon (ăk'sŏn): the thread-like, branching part of a nerve cell, over which impulses travel away from the nucleus of the cell (p. 377).

bacillus* (b*ȧ* sĭl'ŭs); *plural,* **bacilli** (b*ȧ* sĭl'ī): any rod-shaped bacterium (p. 278).

bacterium** (băk tēr'ĭ ŭm); *plural,* **bacteria** (băk tēr'ĭ *ȧ*): a microscopic, one-celled, fungus plant (a bacillus, a coccus, or a spirillum) (p. 277).

balance of nature: a natural condition in which the plants and animals of a given locality maintain their numbers with relatively small changes (p. 32).

basal metabolism (bās'ăl mĕ tăb'ō lĭzm): the rate at which oxygen is used in changing food to other forms of energy in a resting organism (p. 216).

behavior*: the reactions, or responses, of a living thing to all the stimuli which, at any given time, it is receiving (p. 356).

biennial* (bī ĕn'ĭ ăl): a flowering plant which lives during two growing seasons and produces seed during only the second one (p. 172).

bile* (bīl), or **gall:** a yellowish-green liquid produced (secreted) by the liver, which passes into the small intestine and there aids and hastens the digestion of fats (p. 236).

biologist** (bī ŏl'ō jĭst): a scientist who is a specialist in the study of plant and animal life (p. 7).

biology** (bī ŏl'ō jĭ): the great branch of science which has to do with the study of plants and animals (p. 7).

bladder** (blăd'ẽr): a bag-like organ in higher animals in which a waste liquid, as urine or bile, collects; or which, in fish and some plants, is filled with air (p. 269).

blastula (blăs'tū l*ȧ*): an early stage in the development of the embryo of an animal, in which it is a hollow ball of cells (p. 460).

blood:** the fluid which circulates throughout an animal's body, bringing food and oxygen to the cells and carrying away cell wastes (p. 249).

"border-line" organism (ôr'găn ĭzm): an organism which has characteristics of both plants and animals (p. 564).

botany** (bŏt′*ȧ* nĭ): the branch of biological science which deals with the study of plants (p. 7).

bronchus (brŏng′kŭs); *plural,* **bronchi** (brŏng′kī): one of the two large branches of the windpipe (trachea) of a higher vertebrate, through which air passes to and from the lungs (p. 261).

Bryophyta (brī ŏf′ĭ t*ȧ*), or **bryophytes** (brī′ō-fīts): the great group, or phylum, of plants which includes the liverworts and mosses (p. 559).

bud**: in plants, a structure within which leaves or flowers develop; in animals, an out-growth from the body which develops into a new animal, as in a hydra or a sponge (p. 431*).

budding*: the natural process of forming a bud; a method of grafting used in propagating artificially many kinds of fruit and ornamental trees, by which a bud from one tree is made to grow upon the stem of another (pp. 430 and 433*).

bug*: an insect belonging to one order (Hemiptera) each member of which has a jointed, beak-like mouth adapted for piercing and sucking (p. 182).

Calorie* (kăl′ō rĭ): the large calorie, a unit of heat energy equal to the amount of heat required to raise the centigrade temperature of one thousand grams, or one kilogram (2.2 pounds), of water one degree (p. 215).

calyx* (kā′lĭks): the outer ring of flower structures, composed of green, leaf-like parts (sepals) (p. 446).

cambium* (kăm′bĭ ŭm): the layer of growing (cell-forming) tissue between the xylem and the phloem of the fibrovascular bundles in the stems of dicots and young monocots (pp. 161 and 164).

capillarity** (kăp ĭ lăr′ĭ tĭ): the rise of liquids through fine tubes or minute spaces, as in plant stems and in the soil (p. 87).

capillary** (kăp′ĭ lĕr ĭ): a minute blood vessel connecting an artery with a vein; a fine tube in plant structures; a small opening into the soil (pp. 87, 255*).

carbohydrate** (kär bō hī′drāt): an energy food, as a sugar, a starch, or a cellulose, which is made up of carbon, hydrogen, and oxygen in a certain definite proportion (p. 197).

carbon* (kär′bŏn): one of the essential chemical elements in all protoplasm and all energy foods (p. 41).

carbon dioxide** (kär′bŏn dī ŏk′sīd): a gas, without taste, odor, or color, which is formed in the cells of plants and animals when food is oxidized, or burned, in them (p. 153).

carnivorous (kär nĭv′ō rŭs): flesh-eating; applied, usually, to the members of the Carnivora (kär nĭv′ō r*ȧ*), an order of mammals which includes cats, dogs, lions, and wolves (p. 55*).

cartilage* (kär′tĭ lĭj), or **gristle** (grĭs′l): a strong, elastic animal tissue which makes up part of the skeleton of a vertebrate, especially of an embryo or a young vertebrate (p. 271).

cell** (sĕl): one of the units of protoplasm of which every plant or animal is composed, and which has a nucleus, and cytoplasm (p. 41).

cell division: the process by which a cell divides into two new cells, in forming body cells or sex cells (p. 439).

cell membrane (mĕm′brān): the outer, less watery part of the protoplasm, which composes an animal cell (p. 42).

cell wall: the outer part of a plant cell, often more or less rigid, or stiff, because it contains cellulose (p. 42).

cellulose* (sĕl′ū lōs): a carbohydrate belonging to the group of carbohydrates which form the hard, stiff material of most plant-cell walls (p. 42).

central nervous system: that part of the nervous system of an animal, especially of a higher vertebrate, which consists of the brain and spinal cord (p. 377).

cerebellum** (sĕr ē bĕl′ŭm): the part of the brain of a vertebrate which controls the muscles and causes them to function together properly (p. 377).

cerebrum** (sĕr′ē brŭm): the large part of the brain of a man, which occupies the upper portion of the skull and in which the centers of speech, hearing, thought, and conscious action are located (p. 377).

character, characteristic, or **trait**** (trāt): a particular feature of a living thing, such as color of a flower, shape of an animal, or size of an organ (p. 471).

chemical (kĕm′ĭ kăl) **change:** a change in the nature of a substance which results in the formation of one or more substances different from the original one, as when wood burns (p. 64).

chlorophyll** (klō′rō fĭl): the green material in plant cells, which is necessary to the food-making process (p. 146).

chloroplast* (klō′rō plăst): a small body, within a plant cell, which manufactures and contains chlorophyll (p. 155*).

Chordata (kôr dā′t*ȧ*), or **chordates**** (kôr′dāts): the great group, or phylum, of animals having a notochord either throughout life, as the lower forms,

or during only the earlier stages of development, as the vertebrates (p. 537).

chromatin (krō'mȧ tĭn): a grainy substance in cell nuclei, which forms into chromosomes (p. 439).

chromosome* (krō'mō sōm): a rod-like structure formed from the chromatin in the nucleus of a cell which is about to divide in the process of forming body cells or sex cells, and composed of genes, which are the carriers of heredity (pp. 439, 482).

chyme (kīm): food in the partly digested condition in which it leaves the stomach (p. 236).

cilia** (sĭl'ĭ ȧ): microscopic, hair-like projections of protoplasm from a cell, which are moved in such a way as to cause either the cell itself to change location or the liquid around it to move in a certain direction (p. 305).

circulation** (sûr kū lā'shŭn): the process by which blood and lymph are forced from one part of an animal's body to another (p. 255).

circulatory (sûr'kū lă tō rĭ) **system***: the system of tubes and other structures through which blood and lymph are forced to all parts of an animal's body (p. 258).

class*: one of the larger divisions of a phylum (p. 55*).

classification (klăs ĭ fĭ kā'shŭn): a plan or scheme by which plants and animals are grouped according to likeness in structure or life history (p. 51).

cloaca (klō ā'kȧ): a short tube through which amphibians, reptiles, birds, and many fishes discharge eggs and sperms, as well as waste materials from the intestines and kidneys (p. 268).

coccus* (kŏk'ŭs); *plural*, **cocci** (kŏk'sī): a ball-shaped bacterium (p. 278).

Coelenterata (sē lĕn tĕr ā'tȧ), or **coelenterates** (sē lĕn'tĕr āts): the great group, or phylum, of invertebrate animals, such as hydras, corals, and jellyfishes, each of which has a two-layered, bag-like body (p. 517).

colchicine (kŏl'chĭ sēn): a chemical compound obtained from the autumn crocus, which has the effect of changing the processes of reduction division in such a way as to double the number of chromosomes in the cells and thus to give rise to new varieties of plants (p. 487).

cold-blooded animal**: any animal, such as an insect, a fish, a frog, or a reptile, whose body temperature varies with the temperature of its surroundings (p. 199).

combustion* (kŏm bŭs'chŭn): burning, or oxidation, that is, the combining of a substance or substances with oxygen (p. 212).

commensalism* (kŏ mĕn'săl ĭzm): the relationship of two organisms of different kinds (1) in which they live together as partners (commensals) and use the same food supply; (2) in which neither partner feeds upon or otherwise harms the other; (3) and in which one or both have increased chances for survival because of this relationship (p. 515).

communicable (kŏ mū'nĭ kȧ bl), or **infectious** (ĭn fĕk'shŭs), **disease****: any disease which may be spread by the direct or indirect transfer of its germs from one living thing to another (p. 277).

complete flower*: a flower having petals, sepals, pistils, and stamens (p. 446).

complete metamorphosis (mĕt ȧ mŏr'fō sĭs): the series of marked changes in form and structure through which most invertebrates (as certain insects) and amphibians (as frogs and toads) pass while developing from egg to adult (p. 181*).

compound**: (adjective) composed of similar parts, as a compound eye or a compound leaf; (noun) any substance composed of two or more elements in chemical combination, as a food substance (pp. 65 and 392).

conditioned response*: an unnatural, or uninherited, response to a stimulus; any learned reaction, as a habit (p. 410).

conifer (kō'nĭ fẽr): any plant, such as a pine, which bears cones (p. 563).

conjugation* (kŏn jo͞o gā'shŭn): a simple method of sexual reproduction in which two like cells unite (p. 434).

conservation** (kŏn sẽr vā'shŭn): the protection and wise use of natural resources (p. 64).

contour (kŏn'to͝or) **plowing**: plowing across the faces of hills, instead of up and down them, so that each furrow is level lengthwise and thus serves to reduce soil erosion resulting from running water (p. 78).

control: in an experiment, any part that gives a basis for the comparison of results or for checking the accuracy of the results (p. 190, the unsprayed insects).

corolla* (kō rŏl'ȧ): all the petals of a flower, as a group (p. 446).

corpuscle** (kôr'pŭsl): one of the small cells that circulate in the blood or lymph, as the red and white corpuscles (p. 250).

cortex* (kôr'tĕks): in plants, an outer protective structure just inside the epidermis of a stem or a root; in animals, the outer layers of cells in such organs as the kidney and the brain (p. 162).

cotyledon** (kŏt ĭ lē'dŭn): a seed leaf of an embryo flowering plant (p. 146).

crop: in animals, an enlarged section of the gullet, in which food is stored before digestion, as in earthworms, insects, and most birds (p. 230).

crop rotation (rō tā'shŭn): the practice of planting a succession of different crops in the same field, to maintain soil fertility and to reduce erosion (p. 80).

cross-fertilization* (fûr tĭ lĭ zā'shŭn): in the sexual reproduction of animals, the uniting of a sperm from one animal with an egg from another (p. 449).

cross-pollination* (pŏl ĭ nā'shŭn): in the sexual reproduction of flowering plants, the depositing of pollen from a stamen of one flower on the pistil of another flower of the same kind (p. 449).

Crustacea (krŭs tā'shē *à*), or **crustaceans** (krŭs-tā'shē ănz): the class of arthropods that includes such animals as crabs, lobsters, crayfish, and shrimps (p. 530).

cycle** (sī'kl): a series of changes that are repeated again and again, such as those in the life history of an insect or of a frog (pp. 160* and 181*).

cytoplasm (sī'tō plăzm): all the protoplasm of a cell except the nucleus (p. 42).

daughter cell: one of the cells resulting from the division of a cell (mother cell), as in the process of growth and of the production of a sperm and an egg (p. 439).

decay**: the processes by which organic matter—that is, the dead bodies, the parts, or the products of plants and animals—is consumed as food by bacteria and other fungi and as a result is changed to simpler substances (p. 97).

deciduous* (dē sĭd'ū ŭs): shedding, or falling off, as the hair of many mammals, the antlers (horns) of deer, or the leaves of trees (p. 154).

deficiency (dē fĭsh'ĕn sĭ) **disease****, or **"hidden hunger"**: a diseased condition or abnormal condition caused by the lack of an essential substance or substances in the diet (p. 295).

dendrite (dĕn'drīt): the branched, tree-like extension of the protoplasm of a nerve cell, over which impulses travel toward the nucleus of the cell (p. 377).

dependent organism* (ôr'găn ĭzm): every animal and every non-green plant, for the reason that, because it is unable to make food, it must depend on green plants for its food supply (p. 46).

dermis* (dûr'mĭs): the sensitive, living, inner layer of skin, beneath the outer layer, or epidermis (p. 303).

diaphragm* (dī'*à* frăm): the sheet of muscle in a mammal's body which separates the chest cavity from the abdominal cavity and which functions in breathing (p. 263*).

dicotyledon* (dī kŏt ĭ lē'dŭn), or **dicot** (dī'kŏt): any flowering plant (angiosperm) having two seed leaves in the embryo stage, as pea or bean (p. 150*).

diffusion** (dĭ fū'zhŭn): the process by which molecules of gases or liquids pass by their own motions among molecules of other kinds of gases or liquids and become distributed there (p. 146).

digestion** (dĭ jĕs'chŭn): the process by which foods are *digested*** (dĭ jĕs'tĕd), or changed into simple compounds in liquid form which can be absorbed and used by living cells (p. 227).

dinosaur* (dī'nō sôr): any member of the group of land-dwelling, non-flying reptiles which existed millions of years ago and are now extinct (p. 466*).

disinfectant* (dĭs ĭn fĕk'tănt): a substance which prevents the growth of disease germs or kills them (p. 318).

division of labor**: in a living thing, the performance of special functions by each of its structures or organs (p. 43).

dominant character* (dŏm'ĭ nănt kăr'ăk tẽr): in heredity, the one of a pair of contrasting characters, or traits, that appears in the offspring of parents each of which has one of these two characters, as tallness in peas, which is dominant over dwarfness (p. 479).

dorsal** (dôr'săl); of or pertaining to the upper part, or back, of an animal: the opposite of *ventral* (p. 537).

ductless (dŭkt'lĕs), or **endocrine** (ĕn'dō krīn), **gland***: a gland without a tube outlet, the products (secretions) of which pass by osmosis directly into the blood stream (p. 232).

echinodermata (ē kī nō dûr'm*à* t*à*), or **echinoderms** (ē kī'nō dûrmz): the great group, or phylum, of animals, such as starfish, sea urchins, and sand dollars, that are commonly called "spiny-skins" because their bodies have a hard or leathery exterior, which, in most cases, is covered with spines (p. 523).

ecology* (ē kŏl'ō jĭ): the branch of biology which deals with the relations of living things with the living and non-living factors of their environment (p. 7).

egg*: a female reproductive cell (ovum); in birds and reptiles, either an unfertilized female reproductive cell (ovum) or a fertilized female reproductive cell (embryo) and its food supply, enclosed in a shell or a membrane (p. 437).

element** (ĕl′ē mĕnt): one of the ninety-two or more substances, such as copper, iron, and oxygen, which cannot be separated into simpler substances (p. 64).

embryo** (ĕm′brĭ ō): a young plant or animal in any of the stages of its development from the fertilized egg-cell (zygote) to the stage in which it is born or is hatched (p. 460*).

endocrine (ĕn′dō krīn), or **ductless, gland*:** a gland without a tube outlet, the products (secretions) of which pass by osmosis directly into the blood stream (pp. 232, 289*).

endoskeleton** (ĕn dō skĕl′ē tŭn): a skeleton, or supporting structure, of bones or other materials inside an animal's body (p. 384*).

enemy* (ĕn′ē mĭ): any organism by which a living thing is attacked, injured, or killed, or any condition by which its existence is made difficult or impossible (p. 45).

energy** (ĕn′ĕr jĭ): the ability or the capacity to do work, that is, to move something or cause something to move (p. 152*).

entomology* (ĕn tō mŏl′ō jĭ): the branch of zoology that treats of insects (p. 535).

environment** (ĕn vī′rŭn mĕnt): all the living and non-living things and conditions among which or in which a plant or an animal lives; the surroundings, or habitat (p. 499).

enzyme** (ĕn′zīm): a substance, produced by a plant or an animal, which causes chemical changes to occur, as in digestion, decay, or fermentation, but which does not itself change during the process (p. 227).

epidermis** (ĕp ĭ dûr′mĭs): in animals, the outer layer of skin; in plants, the outer layer of cells on stems, leaves, and other structures (p. 153).

erosion* (ē rō′zhûn): the processes by which higher elevations of the earth's surface are worn off by wind, running water, and other agents, and are carried to lower levels (p. 67).

esophagus** (ē sŏf′*ȧ* gŭs), or **gullet** (gŭl′ĕt): the part of the food tube, or alimentary canal, which leads from the back of the mouth to the crop (as in earthworms and birds) or to the stomach (as in fish, amphibians, reptiles, and mammals) (p. 230).

experimental (ĕks pĕr ĭ mĕn′tăl) **factor:** the one factor or condition in an experiment that is different from any in the accompanying control experiment; the factor or condition the effects of which are what the experimenter wishes to determine (p. 190, the effects of DDT).

evergreen*: any plant, commonly a cone-bearing one, which sheds its leaves gradually and thus remains green throughout the year (p. 154).

excreta (ĕks krē′t*ȧ*): waste materials given off by an animal (p. 239).

excretion** (ĕks krē′shŭn): the processes by which wastes are removed from the cells and from the bodies of living things; the waste material given off by living things (p. 267).

exoskeleton** (ĕk sō skĕl′ē tŭn): the external, hard, protective body-covering of such animals as crabs, crayfish, and insects (p. 527).

exterminate (ĕks tûr′mĭ nāt): to kill all of any kind of organism (p. 27).

external respiration (ĕks tûr′năl rĕs pĭ rā′shŭn): the osmosis of oxygen from lungs, gills, or breathing-tubes into the blood, and, at the same time, the osmosis of carbon dioxide and water out of the blood and into these organs (p. 242).

extinct* (ĕks tĭngkt′): no longer found alive on the earth (p. 22*).

family*: a subdivision of an order, as the cat family or the rose family (p. 55).

fat:** an energy food of the type (the fats) that produces more Calories of heat energy per gram when burned (oxidized) in living cells than an energy food of any other type (the sugars, the starches, or the celluloses) (p. 170).

fatty acid: a compound formed in the digestion of fats (p. 237).

fauna (fô′n*ȧ*): all the animals of a given region or period (p. 17).

fermentation (fûr mĕn tā′shŭn): the process by which yeasts and bacteria change sugar into alcohol and carbon dioxide (p. 559).

fertilization** (fûr tĭ lĭ zā′shŭn): in biology, the stage in the process of sexual reproduction in which a sperm unites with an egg cell; in agriculture, the addition to the soil of substances needed for plant growth (p. 437).

fibrovascular (fī brō văs′kū lĕr) **bundles*:** a continuous system of tissues of phloem and xylem, composed of thick-walled supporting cells and fibers and of long, thin-walled cells, through which sap flows to all parts of a plant (p. 153).

filament (fĭl′*ȧ* mĕnt): a thread-like body or structure; in a flower, the stem of the stamen; in a fish, one of the divisions of the gills (p. 447*).

fission* (fĭsh′ŭn): the simplest type of asexual reproduction—that in which a simple plant or animal divides to form two (p. 428).

flagellum* (fl*ȧ* jĕl′ŭm); *plural*, **flagella** (fl*ȧ* jĕl′*ȧ*):

a long, hair-like or whip-like projection of protoplasm by means of which certain one-celled organisms and certain cells swim about (p. 564).

flatworm (flăt′wûrm): an animal, as a tapeworm or a fluke, belonging to the great group, or phylum (Platyhelminthes), of worms that have soft, thin, unsegmented bodies (p. 284).

flora (flō′rȧ): all the plants of a given region or period (p. 569).

flower:** the structure of an angiosperm, or flowering plant, which contains the reproductive organs (stamens or pistils, or both), together, usually, with other structures, such as petals and sepals (p. 446).

food:** any substance which provides energy in a living cell or material for building new protoplasm, or which is essential to the good health of an organism (p. 197).

fossil* (fŏs′ĭl): any evidence of life now extinct (p. 467).

fruit*: a ripened plant-ovary, together with its seeds and sometimes also with other flower structures (p. 453).

function** (fŭngk′shŭn): (noun) the action or use of a structure, or the purpose served by it; (verb) to act, to operate (p. 43).

fungus** (fŭng′gŭs); *plural,* **fungi** (fŭn′jī): a non-green plant, as a mold, a yeast, or a mushroom, belonging to the great group, or phylum (Thallophyta), of simplest plants (p. 557).

gall bladder (blăd′ĕr): a muscular, bag-like organ in which gall, or bile, manufactured by the liver, is stored (p. 236).

gamete (găm′ēt): a reproductive cell, as a sperm or an egg (p. 436).

gametophyte (gȧ mē′tō fīt): the sexual generation, or that which produces eggs and sperms, in plants which reproduce by alternation of generations (p. 443).

ganglion* (găng′glĭ ŭn): a nerve center consisting of a mass of nuclei of neurons, or nerve cells (p. 377).

gastric** (găs′trĭk): having to do with the stomach, as gastric glands (p. 236).

gastric (găs′trĭk) **juice*:** the digestive fluid produced by glands in the walls of the stomach, which contains hydrochloric acid and certain enzymes (p. 236).

gastrula (găs′trŏŏ lȧ): the stage in the development of an embryo in which it has a cup-like, or "raspberry-shaped," structure composed of two layers of cells (p. 459).

gene* (jēn): one of the small parts of a chromosome, which are the unit carriers, or determiners, of hereditary traits, or characters (p. 482).

genetics (jē nĕt′ĭks): the branch of biology which deals with heredity (p. 482).

genus* (jē′nŭs); *plural,* **genera** (jĕn′ĕr ȧ): in the classification of plants and animals, the division between family and species (p. 53).

germ** (jûrm): a pathogen, that is, an organism or a "border-line" body (as a virus) which causes a disease; the embryo in a seed (p. 278).

germicide (jûr′mĭ sīd): a germ-killing substance (p. 318).

germination** (jûr mĭ nā′shŭn): the act or the process of sprouting; the beginning of growth, as of a seed or a pollen grain (p. 175).

gill (gĭl): a structure of fish and certain other water animals, through which oxygen dissolved in the water passes by osmosis into the blood, and carbon dioxide and excess water pass out by osmosis into the water (p. 245)

gizzard (gĭz′ĕrd): a muscular digestive organ of most birds and of many invertebrates, in which food is ground up and thus made ready for digestion (p. 230).

gland:** a plant structure or an animal structure which secretes, or produces, a particular substance, such as perfume, egg-shell, perspiration, saliva, or bile (p. 230).

glycerol (glĭs′ĕr ōl), or **glycerin** (glĭs′ĕr ĭn): a product formed by the digestion of fats (p. 227).

glycogen* (glī′kō jĕn): a carbohydrate, sometimes called "animal starch," which is stored in the liver and which serves as a supply of energy for emergencies (p. 259).

goiter (goi′tĕr): a diseased condition resulting from an enlarged thyroid gland (p. 291).

grafting*: any one of several processes of artificial vegetative propagation by which a part of one organism is made to grow as a part of another (p. 433).

green manure: any crop which is plowed under to enrich the soil (p. 99).

growth:** the increase in size of a living thing as a result of mitosis, or the multiplication of cells (p. 201).

guard cell*: one of the two epidermal cells which together surround a stomate, or opening into a leaf, and regulate its size (p. 153).

gullet** (gŭl′ĕt), or **esophagus** (ē sŏf′ȧ gŭs): the portion of the food tube, or alimentary canal, which leads from the back of the mouth to the crop (as in

insects, birds, and earthworms) or to the stomach (as in fish, amphibians, reptiles, and mammals) (p. 231).

gymnosperm (jĭm'nō spŭrm): any plant, as a pine, a spruce, or a fir, which produces seeds that are not enclosed in an ovary (p. 563).

habit*: a type of conditioned response, or behavior, which must be learned, but which thereafter is automatic (p. 412).

habitat** (hăb'ĭ tăt): the surroundings, or environment, in which a plant or an animal lives (p. 19).

heart**: a muscular, chambered organ which, by alternately contracting and relaxing, forces blood through the circulatory system to all parts of an animal's body (p. 256*).

hemoglobin* (hē mō glō'bĭn): a compound of iron in the red corpuscles of the blood, which functions chiefly in combining with oxygen and distributing it to all the cells of the body (p. 250).

herbivorous (hûr bĭv'ō rŭs): plant-eating, as applied to such animals as cows, horses, and sheep (p. 233).

hereditary (hē rĕd'ĭ tĕr ĭ): passed on from parents to offspring by means of the chromosomes in the reproductive cells (p. 473).

heredity** (hē rĕd'ĭ tĭ): biological inheritance, or the passing on of characteristics from one generation to another (p. 473).

hermaphrodite* (hûr măf'rō dīt): a plant or an animal, such as a melon plant or an earthworm, which has both male and female sex organs (p. 437).

hibernation* (hī bĕr nā'shŭn): the act of passing the winter in a dormant (inactive) state (p. 199).

"hidden hunger,"** or **deficiency** (dē fĭsh'ĕn sĭ) **disease:** a diseased or abnormal condition caused by the lack of an essential substance or substances in the diet (p. 93).

homologous* (hō mŏl'ō gŭs): corresponding in development, general structure, and location on or in the body, but not always corresponding in function, as a bird's wing and a horse's foreleg (p. 51).

hormone** (hôr'mōn): a chemical compound which is produced by a ductless (endocrine) gland and which regulates specific bodily processes (p. 232).

host**: a plant or an animal which is attacked by a parasite, or on which or inside which a commensal lives (p. 19).

humus (hū'mŭs): decaying or decayed plant and animal bodies, parts, or products, in soil (p. 66).

hybrid* (hī'brĭd): the offspring resulting from the mating of parents of different varieties or different species, or of parents with different traits (p. 477).

hybridization* (hī brĭd ĭ zā'shŭn): the process of producing hybrids (p. 477).

hydrochloric (hī drō klō'rĭk) **acid:** a compound of hydrogen and chlorine which is produced in small quantities by glands in the walls of the stomachs of the higher animals (p. 236).

hydrogen** (hī'drō jĕn): one of the essential chemical elements in all protoplasm, water, and energy foods (p. 65).

hypothesis* (hī pŏth'ē sĭs): one of the elements of scientific method; a statement or a discussion proposed as a possible explanation or solution of a problem; a reasonable guess regarding what may be expected to happen under given conditions (p. 570).

immunity* (ĭ mū'nĭ tĭ): the ability to resist the attacks of disease germs or conditions causing a disease (p. 322).

inbreeding (ĭn'brēd ĭng): the mating of closely related plants or animals (p. 490).

incomplete metamorphosis (ĭn kŏm plēt' mĕt-*ȧ* môr'fō sĭs): the series of relatively small changes in form and structure through which some invertebrates (as grasshoppers and squash bugs), and all vertebrates except the amphibians, pass while developing from the egg to the adult stage (p. 181*).

incubation (ĭn kū bā'shŭn): the process of hatching eggs; the development of disease germs within the body of a host from the time when the germs enter the body to the time when the symptoms of the disease appear (p. 287).

independent organism* (ôr'găn ĭzm): a green plant, that is, a plant that can make its food (p. 45).

infection** (ĭn fĕk'shŭn): a disease caused by germs; the act of causing a disease by spreading germs from one individual to another (p. 185).

infest (ĭn fĕst'): to enter into or live upon an organism in large numbers, as when fleas or parasitic worms infest a dog (p. 283).

ingestion** (ĭn jĕs'chŭn): the act or process of taking in food (p. 184).

inheritance (ĭn hĕr'ĭ tăns): the reception of characters from preceding generations (p. 473).

inoculation* (ĭn ŏk ū lā'shŭn): the act of injecting a disease-producing vaccine or serum into a plant or an animal for the prevention or the treatment of a disease (p. 297).

inorganic** (ĭn ôr găn'ĭk): in biology, having to do with a substance, such as water or gold, which is neither a part nor a product of a living thing (p. 29).

Insecta (ĭn sĕk′tȧ), or **insects:** the class of animals belonging to the great group, or phylum, Arthropoda, the members of which have three body regions, to the middle one of which (the thorax) are attached three pairs of legs and usually, also, one or two pairs of wings (p. 530).

insecticide (ĭn sĕk′tĭ sīd): any substance (such as DDT) used to kill insects (p. 185).

instinct* (ĭn′stĭngkt): a complex pattern or series of reactions to stimuli, as nest-building (p. 361).

insulin* (ĭn′sū lĭn): a hormone which is produced by certain cells of the pancreas and osmosed directly into the blood, and which is necessary for the normal use of sugar by the body (p. 292).

internal respiration (rĕs pĭ rā′shŭn): the passage of oxygen, by osmosis, from the blood of animals into the cells, and, at the same time, the similar passage of carbon dioxide from the cells into the blood (p. 242).

intestinal (ĭn tĕs′tĭ năl) **juice*:** the part of the digestive fluid in the small intestine, which contains several enzymes secreted by glands in the intestinal walls (p. 230).

intestine** (ĭn tĕs′tĭn): the entire food tube of some of the simpler invertebrates; the part of the food tube, or alimentary canal, posterior to (after) the stomach of higher invertebrates and all vertebrates (p. 230).

invertebrate** (ĭn vûr′tē brāt): (noun) an animal having no backbone, that is, any animal that is not a chordate; (adjective) pertaining to such an animal (p. 513).

involuntary (ĭn vŏl′ŭn tĕr ĭ) **action*:** any action or reaction not controlled by the will, and hence not controlled by the cerebrum of the brain (p. 358).

involuntary (ĭn vŏl′ŭn tĕr ĭ) **muscle:** any muscle not under the control of the will, and hence not under the control of the cerebrum of the brain; an unstriped, or smooth, muscle, such as is in the walls of the digestive system, blood vessels, and bladder (p. 385).

iris (ī′rĭs): the colored part of a camera eye, beneath the outer layer (cornea) and surrounding the pupil (p. 393).

irritability** (ĭr ĭ tȧ bĭl′ĭ tĭ), or **sensitivity** (sĕn-sĭ tĭv′ĭ tĭ): the ability to respond to stimuli, such as changes in the surroundings (p. 356).

kidney** (kĭd′nĭ): an organ which extracts water, urea, and other cell wastes, from the blood (p. 265).

kingdom: one of the two great divisions of living things, which includes all the plants or all the animals (p. 53).

large intestine*: in certain higher invertebrates and in most vertebrates, the portion of the intestine which is posterior to (after) the small intestine (p. 238).

larva** (lär′vȧ); *plural,* **larvae** (lär′vē): the first stage, after hatching from the egg, in the life history of an invertebrate that undergoes complete metamorphosis, as the worm-like stage of a house-fly or a moth (p. 28).

larynx* (lăr′ĭngks): the upper part of the windpipe, or trachea; in mammals and amphibians, the organ of voice (p. 263).

legume* (lĕg′ūm): a plant, as bean, clover, peanut, pea, or locust tree, that bears its seeds in pods (p. 96).

lens (lĕnz): of an eye, the transparent structure, with curving surfaces, that focuses light upon light-sensitive nerves, or the retina (p. 393).

lenticel (lĕn′tĭ sĕl): a small, slit-like opening, or "breathing pore," in the young bark of a woody plant, through which gases pass in and out (p. 164).

lichen* (lī′kĕn): an association of an alga and a fungus, by which they live together with benefit to both (p. 557).

ligament* (lĭg′ȧ mĕnt): a tough, elastic tissue which holds together two adjacent bones of a vertebrate's skeleton (p. 385).

liver** (lĭv′ĕr): in a higher vertebrate, the large, reddish-brown gland, in the digestive cavity, which performs such important functions as producing bile, storing glycogen, and breaking up red corpuscles (p. 259*).

liverwort (lĭv′ĕr wûrt): a member of the class of small green plants which, together with the mosses, make up the phylum of bryophytes (p. 559).

loam* (lōm): soil consisting of a mixture of sand, clay, and humus (p. 174).

locomotion** (lō kō mō′shŭn): the changing by an organism of its location, under its own power, by flying, swimming, walking, crawling, or hopping (p. 46).

lung:** the organ of breathing in air-breathing vertebrates (p. 261).

lymph** (lĭmf): the part of the blood plasma that flows out through the walls of the capillaries and surrounds the body cells (p. 254).

lymphatic (lĭm făt′ĭk) **system*:** the system of lymph glands and tubes through which the lymph passes on its way back from the cell spaces into the blood stream (p. 260).

malnutrition (măl nū trĭsh'ŭn): a condition of poor health resulting usually from an insufficient or improper diet (p. 92).

mammal** (măm'ăl): a member of the highest group (class) of vertebrates, which feeds its young with milk produced by (mammary) glands (p. 547).

marine*: pertaining to the sea, or ocean (p. 523).

maturity* (mȧ tū'rĭ tĭ): the state of having reached full growth and the stage at which reproduction can occur (p. 367).

medulla oblongata** (mē dŭl'ȧ ŏb lŏng gā'tȧ): the bulb-like, posterior (hind) region of the brain of a chordate, which controls many involuntary actions, as breathing and swallowing, and which connects the brain and the spinal cord (p. 381).

medullary (mĕd'ŭ lĕr ĭ) **ray**, or **pith ray**: one of the thin, wedge-like tissues of pith cells, extending from the middle to the bark or dicot stems, and functioning in carrying water and foods to cells not directly served by the phloem and xylem (p. 160).

meiosis (mī ō'sĭs), or **reduction division**: the process which takes place in the nucleus of the mother cell (a body cell) before it divides into sex cells, (sperms or eggs), and by which the number of chromosomes in each sex cell is reduced to one half the number in each body cell (p. 439).

membrane** (mĕm'brān): a thin, soft sheet, or tissue; the thicker, outer portion of an animal cell (p. 151).

metabolism** (mĕ tăb'ō lĭzm): the sum total of all the processes concerned with the use of food by a living thing (p. 215).

metamorphosis** (mĕt *ȧ* môr'fō sĭs): the series of changes in form and structure through which an animal passes as it develops from the egg stage to the adult (p. 182).

Metazoa* (mĕt *ȧ* zō'*ȧ*), or **metazoans** (mĕt *ȧ* zō'-ănz): the great group (subkingdom) of animals which includes all whose bodies are composed of more than one cell (p. 513).

microbe* (mī'krōb): any microscopic plant or animal, especially a disease germ (p. 278).

micro-organism* (mī krō ōr'găn ĭzm): any living thing so small that it can be seen only with the aid of a microscope (p. 29).

microscope** (mī'krō skōp): an instrument that magnifies small objects enough so that they can be studied (p. 572*).

microscopic** (mī krō skŏp'ĭk): so small as not to be visible except through a microscope (p. 19).

migration** (mī grā'shŭn): a movement, usually seasonal and by large groups of animals, from one locality or habitat to another, as when birds go south in the fall and return in the spring (p. 26).

mildew* (mĭl'dū): any one of several specific plant diseases caused by certain fungus parasites; one of the members of certain families of fungi which include both parasites and saprophytes (p. 184).

mineral* (mĭn'ĕr ăl): an inorganic compound from which plants and animals secure elements that they need in making their various structures (p. 66).

mitosis (mī tō'sĭs): a process taking place in the nucleus of a dividing body cell which results in the formation of two new body cells and hence in the growth of the organism; a process of cell division in which the number of chromosomes in the nucleus of each of the two resulting body cells is the same as that of the parent cell (p. 438).

mixture** (mĭks'tūr): a material composed of two or more substances, either elements or compounds, or both, as air or soil (p. 65).

mold* (mōld): one of the members of several classes of fungi which include both parasites and saprophytes (p. 559).

molecule* (mŏl'ē kūl): the smallest unit of any substance that can exist separately; a unit of matter composed of one or more atoms (p. 147).

Mollusca (mō lŭs'k*ȧ*), or **mollusks** (mŏl'ŭsks): the great group, or phylum, of invertebrates, including land and water forms, as snails, clams, and octopuses, each having a soft body that is usually enclosed in a shell, and a foot that is used for locomotion, food-getting, or digging (p. 524).

molt (mōlt): to shed feathers, fur, hair, or any other skin covering (as an exoskeleton) or the skin itself (pp. 182, 270*).

monocotyledon* (mŏn ō kŏt ĭ lē'dŭn), or **monocot** (mŏn'ō kŏt): any flowering plant having only one seed leaf in the embryo stage, as corn or wheat (p. 146).

motor nerve*: any nerve (neuron) along which impulses pass to cause a muscle to respond (p. 377).

mucous membrane** (mū'kŭs mĕm'brān): a soft, moist tissue which lines the alimentary canal and all other tubes which lead to the outside of the body; which is composed of two layers, corresponding to the two layers of skin; and which contains glands that produce mucus (p. 304).

mucus** (mū'kŭs): a thick, slippery liquid produced by glands in the mucous membranes and in the skins of certain animals, as fish (p. 232).

mulch (mŭlch): a loose covering of crop residues, leaves, or powdered soil, which serves to protect

plant roots from freezing, to conserve soil water, and to prevent soil erosion (p. 79).

muscle: an organ composed of cells which can contract (shorten) and relax (lengthen), thus causing body movements (p. 382).

mutant* (mū'tănt): a plant or an animal possessing a new and markedly different hereditary character from any possessed by its ancestors (p. 471).

mutation* (mū tā'shŭn): a marked inheritable variation in one or more characters; a mutant, or an organism showing such a change (p. 471).

natural barrier: a natural obstacle to the spread of living things, such as a jungle, an ocean, or a mountain range (p. 31).

natural selection: selection by nature, that is, the continuing tendency for those plants and animals of each generation which are least well fitted, or adapted, to the habitat, to die off, and for those which are best fitted, to reach maturity and reproduce in greater proportions, with the result that each generation is better fitted to survive than its parent generation (p. 473).

naturalist (năt'ū răl ĭst): a biologist who studies plants and animals in their usual habitats (p. 7).

Nemathelminthes (nĕm *ȧ* thĕl mĭn'thēz), or **roundworms** (round'wûrmz): the one of the three great groups, or phyla, of worms, which includes the hookworm and horse-hair snake, whose bodies are round and unsegmented (p. 522).

nerve**: a strand, or bundle, of tissue which is composed of the axons and dendrites of many nerve cells (neurons) and which connects the nervous system with some other part of the body (p. 377).

nervous (nûr'vŭs) **system:** the system composed of the brain, spinal cord, nerves and nerve cells, by means of which an animal is aware of its environment and is able to react to it (p. 377).

neuron** (nū'rŏn): a nerve cell (p. 377).

nitrate* (nī'trāt): a chemical compound which is made up of nitrogen, and usually also some metal, as sodium or potassium, and which is essential to the growth of certain, or perhaps most, plants (p. 96).

nitrogen** (nī'trō jĕn): one of the essential chemical elements in all protoplasm and proteins (p. 98).

nitrogen-fixing bacteria* (nī'trō jĕn fĭk'sĭng băk tēr'ĭ *ȧ*): certain kinds of soil bacteria, found in the roots of pod-bearing plants (legumes), which combine nitrogen from the air with oxygen and other substances to form nitrates (p. 96).

nodule (nŏd'ūl), or **tubercle** (tū'bẽr kl): a small, rounded growth on the root of a pod-bearing plant (legume), within which nitrogen-fixing bacteria live (p. 97).

non-energy food*: one of the foods, such as water, minerals, and vitamins, which cannot be burned in living cells, and hence from which no energy is obtained (p. 197).

notochord* (nō'tō kôrd): a dorsal rod of cartilage which supports the spinal cord in one of the simplest chordates (p. 539).

nucleus** (nū'klē ŭs); *plural*, **nuclei** (nū'klē ī): a mass of dense protoplasm, often ball-shaped and usually near the middle of a cell, in which are the bodies (chromosomes) that transmit hereditary characters (p. 42).

nutrition** (nū trĭsh'ŭn): all the processes by which plants and animals use food (p. 219*).

nymph** (nĭmf): the immature form of an insect of any of the kinds that undergo incomplete metamorphosis (p. 182).

order*: in the classification of plants and animals, the chief subdivision of a class (pp. 55, 551*).

organ**: any group of tissues, such as an eye or a heart, which work together to perform some special function (p. 43).

organic** (ôr găn'ĭk): in biology, having to do with any substance, as flesh or milk, which is a part or a product of a living thing (p. 29).

organism** (ôr'găn ĭzm): any plant or animal (p. 5).

organ-system, or **system****: a group of organs each of which performs a part of a process, such as digestion, respiration, or circulation (p. 43).

osmosis** (ŏs mō'sĭs): a form of diffusion in which certain liquids, and certain gases and solids in solution, pass through moist membranes or through the walls of living cells (p. 151).

ovary** (ō'v*ȧ* rĭ): in animals, an egg-producing organ; in plants, an organ at the base of the pistil of a flower, in which ovules, containing egg cells, develop (p. 438).

ovule* (ō'vūl): a structure within the ovary of a flower which contains an egg cell and from which a seed containing an embryo plant develops after the egg cell has been fertilized by a sperm from a pollen cell (p. 446).

oxidation** (ŏk sĭ dā'shŭn): the process by which oxygen combines with, or oxidizes, some other substance (as when food is used in the cells) and releases heat or other forms of energy (for use by the organism) (p. 156).

oxygen** (ŏk'sĭ jĕn): a colorless, odorless, and tasteless gas which exists as an element in the air; which is needed by living things for the oxidation of food; and which is a part of all protoplasm (p. 65).

palisade (păl ĭ sād') **tissue***: the tissue composed of long, green cells in a leaf, usually found in rows beneath the upper epidermis (p. 153).

pancreas** (păn'krē ăs): a gland located near the stomach, which produces various digestive enzymes and the hormone insulin (p. 232).

parasite** (păr'ȧ sīt): an organism which lives upon or within another (the host), and which obtains its food at the host's expense (p. 19).

parasitic** (păr ȧ sĭt'ĭk): being, or characteristic of, a parasite (p. 19).

parasitism* (păr'ȧ sīt ĭzm): the condition of being a parasite (p. 19).

pathogen (păth'ō jĕn): a disease germ; any plant or animal that causes a disease (p. 277).

pelvis* (pĕl'vĭs): in most vertebrates, the structure of bones that supports, and to some extent protects, the abdominal organs, and to which the hind legs are attached (p. 384*).

penicillin* (pĕn ĭ sĭl'ĭn): a substance which is obtained from a certain species of mold and which is effective in the treatment of some bacterial diseases (p. 327*, 328).

perennial* (pẽr ĕn'ĭ ăl): (*adjective*) continuing to live more than two years; (*noun*) any plant living more than two years (p. 172).

perfect flower*: any flower which has stamens and one or more pistils, but not necessarily sepals or petals (p. 447).

pericardium (pĕr ĭ kär'dĭ ŭm): the thin, bag-like membrane surrounding the heart (p. 258).

peristalsis (pĕr ĭ stăl'sĭs): wave-like muscular movements in the walls of the digestive canal, which force food through the canal (p. 233).

perspiration** (pûr spĭ rā'shŭn), or **sweat**: water containing dissolved salt and other waste materials which is given off by the sweat glands in the skin (p. 305*).

petal* (pĕt'l): one of the leaf-like flower parts, colored, but rarely green, which surround the stamen and pistil; one of the flower parts which compose the corolla (p. 446).

phloem* (flō'ĕm): the cylinder of tissues in the outer part of the fibrovascular bundle of a higher plant, through which sap carries dissolved food that has been manufactured in the leaves (p. 161).

photosynthesis** (fō tō sĭn'thē sĭs): the process by which sugar is made in plant cells from water and carbon dioxide, in the presence of chlorophyll, and with light as the source of energy (p. 154).

phylum** (fī'lŭm); *plural*, **phyla** (fī'lȧ): a large division, usually a principal one, of the plant or the animal kingdom (p. 56).

physiology** (fĭz ĭ ŏl'ō jĭ): the branch of biological science which deals with the life processes of plants or animals (p. 207).

pistil* (pĭs'tĭl): the female part of a flower, or the part that contains the ovules, which, if fertilized, develop into seeds (p. 446).

pistillate (pĭs'tĭ lāt): having to do with female flowers, that is, those that have pistils only (p. 447).

pith: soft, spongy tissue composed of thin-walled, dead cells, in the stems of flowering plants, as corn and willow (p. 160).

pith ray, or **medullary** (mĕd'ŭ lĕr ĭ) **ray**: a thin, wedge-like sheet of tissue composed of pith cells in a woody plant, which extends from the middle to the outside of the stem and which carries sap to cells not supplied by the phloem or the xylem (p. 160).

plasma** (plăz'mȧ): the liquid portion of the blood (p. 249).

Platyhelminthes (plăt ĭ hĕl mĭn'thēz), or **flatworms** (flăt'wûrmz): the one of the three great groups, or phyla, of worms, which include the tapeworms and the flukes, whose bodies are soft, flat, and unsegmented (p. 518).

pleura (plo͝or'ȧ): a thin, bag-like membrane which lines the chest cavity and completely encloses the lungs (p. 262).

pollen** (pŏl'ĕn): the asexual spores of seed plants, which are produced within the anthers of the stamens and within which the male sex cells (sperms) develop (p. 447).

pollination** (pŏl ĭ nā'shŭn): the transfer of pollen from a stamen to a pistil of a flower, as by wind or insects (p. 447).

pollution (pō lū'shŭn), or **contamination** (kŏn-tăm ĭ nā'shŭn): any process or condition by which disease germs get into drinking water or food and render it unsafe for use (p. 135).

Porifera (pō rĭf'ẽr ȧ), or **sponges**: the great group, or phylum, of animals which is made up of the sponges (p. 514).

posterior** (pŏs tēr'ĭ ẽr): toward the rear of an animal; the opposite of anterior (toward the head) (p. 540).

predator* (prĕd'*ȧ* tẽr): any animal, such as a lion or a wolf, which secures food by preying upon, or attacking, other living things; commonly, an animal that kills and eats another (p. 26).

primitive* (prĭm'ĭ'tĭv): pertaining to the earliest stages of development of a kind of plant or animal (p. 303).

principle* (prĭn'sĭ pl): a generalization, that is, a statement that is true of many, or perhaps of all, organisms (p. 37).

progeny (prŏj'ĕ nĭ): offspring, or young, as sons and daughters (p. 472).

propagation* (prŏp *ȧ* gā'shŭn): the act or process of producing young by natural or by controlled reproduction (p. 430).

protein** (prō'tē ĭn): a food made up of nitrogen, carbon, hydrogen, and oxygen, and usually, also, sulfur and other elements, which can provide energy, but which is necessary for the building of protoplasm (p. 170).

protoplasm** (prō'tō plăzm): the living material of which cells are composed (p. 41).

Protozoa** (prō tō zō'*ȧ*), or **protozoans** (prō tō-zō' ănz): the great group, or phylum, of animals with one-celled bodies (p. 513).

Pteridophyta (tĕr ĭ dŏf'ĭ t*ȧ*), or **pteridophytes** (tĕr'ĭ dō fīts): the great group, or phylum, of plants which is composed of the ferns, club mosses, and horsetails (p. 560).

pulmonary* (pŭl'mō nĕr ĭ): of the lungs, or pertaining to the lungs (p. 258).

pulse* (pŭls): the alternate increase and decrease of pressure in an artery as the blood is forced through it by the heart-beat (p. 258).

pupa** (pū'p*ȧ*): the resting stage, between the larval and the adult stage, in the life of an insect that undergoes complete metamorphosis; an insect in this stage (p. 182).

quarantine (kwŏr'ăn tēn): a means of reducing the spread of communicable diseases, through the prevention, by law, of the mingling of people, plants, or animals having communicable diseases, or suspected of carrying such diseases, with others not thus infected (p. 317).

reaction (rē ak'shŭn), or **response**** (rē spŏns'): any action resulting from a stimulus, as a change in the environment (p. 355).

recessive (rē sĕs'ĭv) **character:** in heredity, one of a pair of contrasting characters, or traits (as dwarfness in peas), which does not appear in the offspring, of parents each of whom has one of these two characters, but which may appear in a later generation if the dominant one (tallness) is absent (p. 479).

red corpuscle (kôr'pŭsl): a disk-shaped blood cell containing the iron compound hemoglobin, by means of which oxygen is distributed to the body cells (p. 250).

reduction division, or **meiosis** (mī ō'sĭs): the series of changes in the nucleus of a cell during the formation of sex cells (sperms and eggs), as a result of which each sperm or egg has only half the number of chromosomes that a body cell of the same organism has (p. 440).

reflex* (rē'flĕks): an immediate, simple, unlearned response to a stimulus, by an animal having a nervous system (p. 360).

reflex arc (rē'flĕks ärk): the path, composed of nerves and nerve cells, by which an impulse passes inward from a sensory nerve ending to the spinal cord and thence outward to a muscle (p. 381).

regeneration* (rē jĕn ẽr ā'shŭn): the healing of an injured structure (as wounded tissue) or the replacing of one that has been lost (as a crab claw) (p. 201).

reproduction** (rē prō dŭk'shŭn): the process of producing offspring, or young (p. 428).

reptile* (rĕp'tĭl): such a chordate as a snake, a turtle, or a lizard, which belongs to the class Reptilia, and which is cold-blooded, has a scale-covered body, and breathes with lungs all its life (p. 542).

respiration** (rĕs pĭ rā'shŭn): the process which includes the passing of oxygen into living cells and the passing of carbon dioxide and surplus water out of them (p. 154).

response** (rē spŏns'), or **reaction** (rē ăk'shŭn): any action resulting from a stimulus, as a change in the environment (p. 355).

rhizoid (rī'zoid): a simple, root-like structure without fibrovascular bundles, which is found in most bryophytes (mosses and liverworts) (p. 70).

rickets (rĭk'ĕts): a deficiency disease which is due to a lack of sufficient quantities of vitamin D in the diet, and which results in abnormal development of bones and teeth (p. 295).

rickettsia (rĭk ĕt'sĭ *ȧ*); *plural,* **rickettsiae** (rĭk-ĕt'sĭ ē): one of the microscopic disease germs which are believed to be non-living and intermediate between one-celled organisms and viruses; named after H. T. Ricketts, who made important studies of Rickettsiae (p. 285).

ringworm (rĭng'wûrm): a disease of the skin or scalp caused by a parasitic fungus plant (p. 280).

rodent* (rō'dĕnt): an animal, such as a rat, a

mouse, or a squirrel, belonging to the order of mammals which are distinguished chiefly by long front teeth adapted for gnawing (p. 123).

roe (rō): the eggs of fish (p. 136).

root hair: a long, hair-like cell of the epidermis of a small root, through the walls of which water, containing dissolved minerals, passes from the soil into the plant (p. 152).

roundworm (round'wûrm): an unsegmented worm, as the hookworm or the trichinosis parasite, which belongs to the phylum Nemathelminthes (p. 281).

rudimentary* (rōō dĭ mĕn'tȧ rĭ): not completely developed and not able to function (p. 392).

rust* (rŭst): one of a group of fungus parasites which cause certain diseases of plants; a plant disease caused by one of these parasites (p. 184).

saliva** (sȧ lī'vȧ): the digestive fluid which is produced by glands in the mouth, and which contains a starch-digesting enzyme and mucus (p. 232).

sanctuary (săngk'tū ĕr ĭ): in biological conservation, an area set aside by national, state, or provincial law, in which wild life is protected from being harmed or molested by man (p. 27).

sap**: the watery liquid, roughly corresponding to blood in animals, which brings dissolved food, minerals, and other necessary substances to the living cells of a plant and carries away waste materials from them (p. 165).

saprophyte** (săp'rō fīt): one of the dependent, or non-green, plants which consume, as food, organic materials—the bodies of dead organisms or the products of organisms, as manure and honey (p. 557).

saprophytic** (săp rō fĭt'ĭk): being, or characteristic of, a saprophyte (p. 557).

saprophytism (săp'rō fīt ĭzm): the condition of being a saprophyte (p. 557).

scavenger (skăv'ĕn jĕr): an animal, such as a turtle, a vulture, a clam, or a crayfish, which feeds on decaying plant or animal bodies or on other decaying organic materials (p. 19).

secrete (sē krēt'): to make, as every gland does, a specific substance which is essential to the life of an organism (as a hormone or a digestive enzyme), or which may be waste material (as perspiration, gum, or pitch) (p. 230).

secretion* (sē krē'shŭn): a specific substance, as a hormone, an enzyme, or a waste substance, made in a gland; the process of making such a substance (p. 232).

seed**: a matured ovule of a flowering plant, containing an embryo, together with enough food to sustain it until it can make its own food (p. 446).

seed plant*: a flowering plant, that is, any plant belonging to the phylum Spermatophyta (p. 562).

segment** (sĕg'mĕnt): one of the sections, or conspicuous body divisions, of such an animal as an earthworm or an insect (p. 523).

self-fertilization* (sĕlf fûr tĭ lĭ zā'shŭn): in sexual reproduction, the union of sperm cells with egg cells produced by the same animal (p. 449).

self-pollination (sĕlf pŏl ĭ nā'shŭn): in sexual reproduction, the pollination of a flower with pollen which it has itself produced (p. 449).

sensation* (sĕn sā'shŭn): a feeling produced by a stimulus, that is, by a change within the body or in the surroundings (p. 386).

sensitive (sĕn'sĭ tĭv): able to respond, or react, to conditions and objects in the environment (p. 386).

sensitivity (sĕn sĭ tĭv'ĭ tĭ), or **irritability**** (ĭr ĭ tȧ bĭl'ĭ tĭ): the ability to respond, or react, to stimuli, or changes in the environment (p. 356).

sensory (sĕn'sō rĭ): related to the sensations or to the neurons that receive stimuli, such as heat, light, sound, and pressure, and that carry the impulses inward toward the spinal cord (p. 377).

sensory (sĕn'sō rĭ) **nerve***: one of the nerves, or bundles of nerve cells (neurons), which carry impulses from a sensory neuron to a nerve center, such as a ganglion or the brain (p. 377).

sensory neuron (sĕn'sō rĭ nū'rŏn): a nerve cell which is sensitive to stimuli, such as heat, light, sound, and pressure, and which carries an impulse inward toward the spinal cord (p. 377).

sepal* (sē'păl): one of the outer, leaf-like structures, usually green, which make up the calyx of a flower and which together enclose and protect the bud before it opens (p. 446).

serum** (sēr'ŭm): a liquid prepared from the blood fluid, which contains antibodies or other disease-resisting substances and which is injected into an animal to prevent or cure a specific disease; the clear, yellow fluid which remains when blood clots (p. 543).

sewage* (sū'ĭj): waste materials from the alimentary canal and the kidneys of higher animals, especially man; the material that is drained away through sewers (p. 558).

sex cell, or **gamete** (găm'ēt): a male cell (sperm) or a female cell (egg, or ovum) (p. 436).

sexual** (sĕk'shōō ăl): having male or female reproductive organs, or both; pertaining to or involving sex (p. 428).

sexual reproduction* (sĕk′shŏŏ ăl rē prō dŭk′-shŭn): reproduction in which two cells, usually a sperm and an egg cell (a male and a female gamete), unite to form an embryo (p. 437).

skeleton** (skĕl′ē tŭn): the hard, internal or external structures which give support and protection to the body or to vital organs (p. 384*).

small intestine* (ĭn tĕs′tĭn): the portion of the intestine immediately posterior to (following) the stomach, in which practically all digestion is completed and through the walls of which nearly all the digested food is absorbed into the blood (p. 236).

smut* (smŭt): one of a group of fungus parasites which cause certain diseases of plants; a plant disease (common in grain plants) caused by one of these parasites (p. 184).

society* (sō sī′ĕ tĭ): a group composed of all the plants and animals living in a given habitat (p. 22).

soil:** a mixture of rock particles, minerals, decaying plant and animal matter (humus), and more or less water (p. 66).

soluble* (sŏl′ū bl): capable of being dissolved (p. 229).

specialization (spĕsh ăl ĭ zā′shŭn): the adaptation or development of a structure for a particular function (p. 43).

species** (spē′shĭz); *plural,* **species** (spē′shēz): a group of plants or animals the members of which are enough alike in structure so that they can readily inter-breed; one of the chief divisions of a genus (p. 53).

sperm** (spûrm), or **male gamete** (găm′ēt): a male reproductive cell (p. 437).

Spermatophyta (spûr mȧ tŏf′ĭ tȧ), or **spermatophytes** (spûr′mȧ tō fīts): the great group, or phylum, of flowering, or seed-producing, plants (p. 562).

spinal (spī′năl) **column, backbone, vertebral** (vûr′tē brăl) **column,** or **spine**:** the series of flat bones (vertebrae) which together enclose and protect the spinal cord of a vertebrate animal (p. 384*).

spinal cord** (spī′năl kôrd): the main nerve cord of a chordate, which in every vertebrate extends from the brain through the backbone (p. 537).

spiracle* (spī′rȧ kl): a breathing pore, or opening into a breathing tube, on the abdomen of an insect (p. 245).

spirillum* (spī rĭl′ŭm); *plural,* **spirilla** (spī rĭl′ȧ): a bacterium having a spiral, or cork-screw-like, shape (p. 280).

spontaneous generation* (spŏn tā′nē ŭs jĕn ĕr-ā′shŭn): the name of an old, false theory which held that living things sometimes were formed and became alive from non-living material (p. 427).

spore** (spōr): a reproductive cell or a resting (dormant) cell of a plant or of a protozoan, which, without uniting with another cell, can produce a new individual (p. 280).

sporophyte (spō′rō fīt): a spore-producing plant; the asexual stage, or generation, or that which produces spores, in the alternation of generations of a plant (p. 444).

stamen** (stā′mĕn): a pollen-producing organ, or male reproductive organ, of a flower (p. 446).

staminate (stăm′ĭ nāt): having to do with male flowers, that is, those that have stamens, but not pistils (p. 447).

starch:** an energy food belonging to the group of carbohydrates that are not soluble in the body fluids of plants and animals, and that are stored as a reserve food supply in various plant tissues (p. 170).

sterile (stĕr′ĭl): free of disease-producing germs; unable to reproduce (p. 335).

sterilization (stĕr ĭ lĭ zā′shŭn): the process by which germs of disease are killed, as by the use of heat or chemicals; the act or process by which an organism is rendered unable to reproduce (p. 334).

stigma* (stĭg′mȧ): the structure at the top of a pistil of a flower, on which pollen grains may germinate (p. 447).

stimulus** (stĭm′ū lŭs); *plural,* **stimuli** (stĭm′-ū lī): a condition, as a change in the surroundings, which causes a response (usually an action) by an organism (p. 355).

stoma (stō′mȧ), or **stomate*** (stō′māt); plural, **stomata** (stō′mȧ tȧ), or **stomates** (stō′māts): a microscopic opening in a plant leaf or a young plant stem, through which gases pass inward and outward (p. 153).

stomach** (stŭm′ăk): a pouch-like organ of the digestive system, in which food is stored until certain processes of digestion within the organ have been completed (p. 231).

sugar:** a sweet-flavored energy food belonging to the group of carbohydrates that are produced in the early stages of photosynthesis in green plants, and that are readily soluble in the body fluids of plants and animals (p. 170).

survival** (sẽr vīv′ăl): of an individual, continuing to remain alive in spite of attacks by enemies and of unfavorable conditions of the habitat; of a species or other group, persisting, or continuing to exist, usually for a long period (p. 473).

survival (sẽr vīv′ĕl) **of the fittest:** the continued existence of those plants and animals of each generation whose variations in structure best fit, or adapt, them to grow to maturity, to reproduce, and thus to

pass on the successful variations to their offspring (p. 473).

symbiosis (sĭm bī ō'sĭs): the living together of two different kinds of organisms, as a fungus and an alga, with resulting benefit to each (p. 557).

symptom* (sĭmp'tŭm): a change in the structure or the function of a plant or an animal, indicating, usually, a diseased condition (p. 293).

taxonomy (tăks ŏn'ō mĭ): the branch of biology that deals with the classification of living things (p. 3).

tendon* (tĕn'dŭn): a strong, flexible band of tissue by which a muscle is attached to a bone (p. 382).

tentacle (tĕn'tȧ kl): one of the slender, flexible appendages of such an animal as a hydra, a jellyfish, or an octopus, which are used in locomotion, food-getting, and defense, and also in various ways as sense organs (p. 519).

terrestrial** (tĕ rĕs'trĭ ăl): living on land (p. 17).

testis** (tĕs'tĭs); *plural,* **testes** (tĕs'tēz): one of the sperm-producing organs of an animal (p. 438).

Thallophyta (thă lŏf'ĭ tȧ), or **thallophytes** (thăl'-ō fīts): the great group, or phylum, which includes the simplest plants, namely, the algae and the fungi (p. 554).

thorax* (thō'răks): in an insect, the middle one of the three chief divisions of the body, to which the wings and legs are attached; in a higher animal, the portion of the body between the abdomen and the neck.

thyroid (thī'roid): in mammals, the ductless gland located just beneath the larynx, or "Adam's apple," and across the windpipe (p. 291).

tissue** (tĭsh'ū): a group, or a mass, of cells of the same kind, performing the same function (p. 43)

tonsil* (tŏn'sĭl): one of the pair of lymph glands at the back of the pharynx, in the throat (p. 260).

toxin** (tŏk'sĭn): any poisonous substance, especially one produced by a disease germ (p. 277).

trachea* (trā'kē ȧ); *plural,* **tracheae** (trā'kē ē): in man and in the other higher animals, the windpipe, or main tube through which air passes between the throat and the lungs in breathing; in most insects, any one of a number of breathing tubes which branch throughout the body (pp. 245, 261).

transpiration** (trăn spĭ rā'shŭn): the process by which water is evaporated from plants, especially higher plants, through the stomata of the leaves (p. 87).

tropism (trō'pĭzm): the simplest response that an organism can make to a stimulus; the response of a plant or a simple animal to such a stimulus as heat, light, gravity, a chemical, or water (p. 358).

tubercle (tū'bẽr kl), or **nodule** (nŏd'ūl): a small, round growth, or swelling, on a plant structure or an animal structure, caused by bacteria, as the nodules on the roots of pod-bearing plants or the tubercles on lung tissue (p. 97).

unit character: a hereditary character, such as eye color or seed color, which is inherited independently of other characters (p. 480).

urea* (ū rē'ȧ): a nitrogen compound which is a waste product formed by the use, or breaking down, of proteins in the cells of plants and animals, and which, in the higher animals, is eliminated as part of the urine (p. 107).

urine* (ū'rĭn): water containing dissolved urea and other cell wastes, which is excreted by the kidneys of animals (p. 268).

vaccination (văk sĭ nā'shŭn): the process of inoculating a plant or an animal with a vaccine (p. 322).

vaccine (văk'sēn): liquid containing dead or weakened germs or their products, which is used in inoculations for the prevention or the treatment of a specific infectious disease, as smallpox (p. 322).

variation** (vâr ĭ ā'shŭn): an inherited difference, in structure or function, from the parents (p. 471).

vascular* (văs'kū lẽr): having to do with the structures, in plants or animals, through which sap passes or blood and lymph pass to the living cells (p. 152).

vascular system:** the succession of tubes, chambers, and organs through which sap passes in a plant or blood and lymph pass in an animal (p. 152).

vegetative reproduction* (vĕj'ē tā tĭv rē prō-dŭk'shŭn): any one of several methods of asexual reproduction, or reproduction by a single parent (p. 430).

vein** (vān): in a higher animal, one of the blood vessels through which blood flows from the capillaries back to the heart; in plants, one of the branches of a fibrovascular bundle which extend into the blade of a leaf (p. 153).

ventral** (vĕn'trăl): of or pertaining to the under part, or abdomen, of an animal; the opposite of *dorsal* (p. 536).

ventricle (vĕn'trĭ kl): a chamber of a vertebrate's heart from which blood is forced by the heart-beat into a main artery (p. 247).

vertebra (vûr'tē brȧ); *plural,* **vertebrae** (vûr'-

tē brē): one of the bones which make up the backbone, or spinal column (p. 539).

Vertebrata (vûr tē brā'tȧ), or **vertebrates**** (vûr'tē brāts): the division in the phylum Chordata in which are classified all the animals with backbones, including the fishes, amphibians, reptiles, birds, and mammals (p. 539).

villus (vĭl'ŭs); *plural*, **villi*** (vĭl'ī): one of the microscopic, finger-like structures in the lining of the small intestine, whose function is the absorption of digested food into the blood (p. 238).

virus* (vī'rŭs): a disease germ, probably a large protein body, having some of the characteristics of a living thing and some of the characteristics of a non-living thing (p. 285).

vitamin** (vī'tȧ mĭn): one of a large group of non-energy food substances produced originally by plants, and necessary to the health and normal development of certain plants or animals or of all plants and animals (p. 207).

voluntary (vŏl'ŭn tĕr ĭ) **action***: an action, such as studying a lesson or picking a flower, that is controlled by the will (p. 362).

warm-blooded animal**: a member of either of the two classes of vertebrates the birds or the mammals, whose body temperature varies only slightly or slowly as the temperature of the environment changes (p. 199).

weathering* (wĕth'ẽr ĭng): the processes by which rocks are broken down into soil by frost, heat, chemical action, etc. (p. 64).

white corpuscle (kôr'pŭsl): one of the colorless blood cells of several types, resembling an ameba in form and movement and having a nucleus (p. 251).

wilt: (verb) to droop for lack of water; (noun) one of a group of fungus parasites which cause certain diseases of plants; (noun) a plant disease caused by one of these parasites (p. 184).

windpipe (wĭnd'pīp), or **trachea** (trā'kē ȧ)—*plural*, **tracheae** (trā'kē ē): the main tube through which air passes between the throat and the lungs in breathing (p. 263).

xylem* (zī'lĕm): the innermost of the three regions of a fibrovascular bundle, through which sap passes upward from the roots to the leaves (p. 161).

yeast* (yēst): any member of a certain family of microscopic, one-celled, non-green fungus plants (p. 557).

zoology** (zō ŏl'ō jĭ): the branch of biology that deals with the study of animals (p. 7).

zygote (zī'gōt): a fertilized egg, or an egg cell after it has united with a sperm cell; the first stage in the development of an embryo (p. 441).

INDEX

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